Drone Formation Control System (DFCS) 915MHz Ground Stations Specification

General Information

Data Link Transmission Protocol

The DFCS data link operates on a single carrier frequency of 915 megahertz. Uplink and downlink messages are digitally coded, and vary in length. A typical message contains about 40 bytes of information and duration of about 750 microseconds. Transmission interference is avoided by sequential message transmissions from various stations, initiated and coordinated by the central processor.

All data link units within line of sight of that station receive transmissions. Not all receiving stations respond, only those selected by the central processor. The action of each receiving station is controlled by the information in the uplink message. The central computer generates this message. Each station has a unique address, so the uplink message can specify which particular stations are to perform the various actions required to complete an uplink/downlink cycle. The designation of “Airborne platform”, “Master”, “Slave”, listen only or “Relay” is the designated role of the stations in a uplink/downlink cycle. The roles of each station can change from cycle to cycle.

A typical data link cycle is (see fig. 1):

> The uplink message is generated at the central processor and passed to the Interrogator Station co-located (ISc). The ISc broadcast the uplink message that starts the data link cycle. The ISc usually broadcasts an uplink message addressed to a Relay station, but may broadcast directly to a master station
>
> The Relay station rebroadcasts the uplink message. This rebroadcast message i may be addressed to another relay, but is usually addressed to a master. Any station can be designated as master or relay.
>
> The Master rebroadcasts the message, now addressed to the transponder onboard the target. Up to four targets may be addressed in an uplink message. The master resets its time-of-arrival (TOA) counter upon transmission of the uplink to the target(s). Receipt of this message by each of the other selected ground stations resets individual time-of-arrival counters in preparation for receipt of an onboard transponder transmission.
>
> Various proportional and discrete control commands are extracted from the uplink message by the onboard transponder. The ground station developer does not require knowledge of the exact contents of these commands. The ground station only needs to rebroadcast those messages.
>
> > Proportional and discrete telemetry signals, received from sensors onboard the drone, are encoded into a downlink message for transmission.

The onboard transponder broadcasts to all participating ground stations (Masters, Slaves, Relay, ISc). All ground stations, including the ISc, sample their time-of-arrival counters upon receipt of the target message.

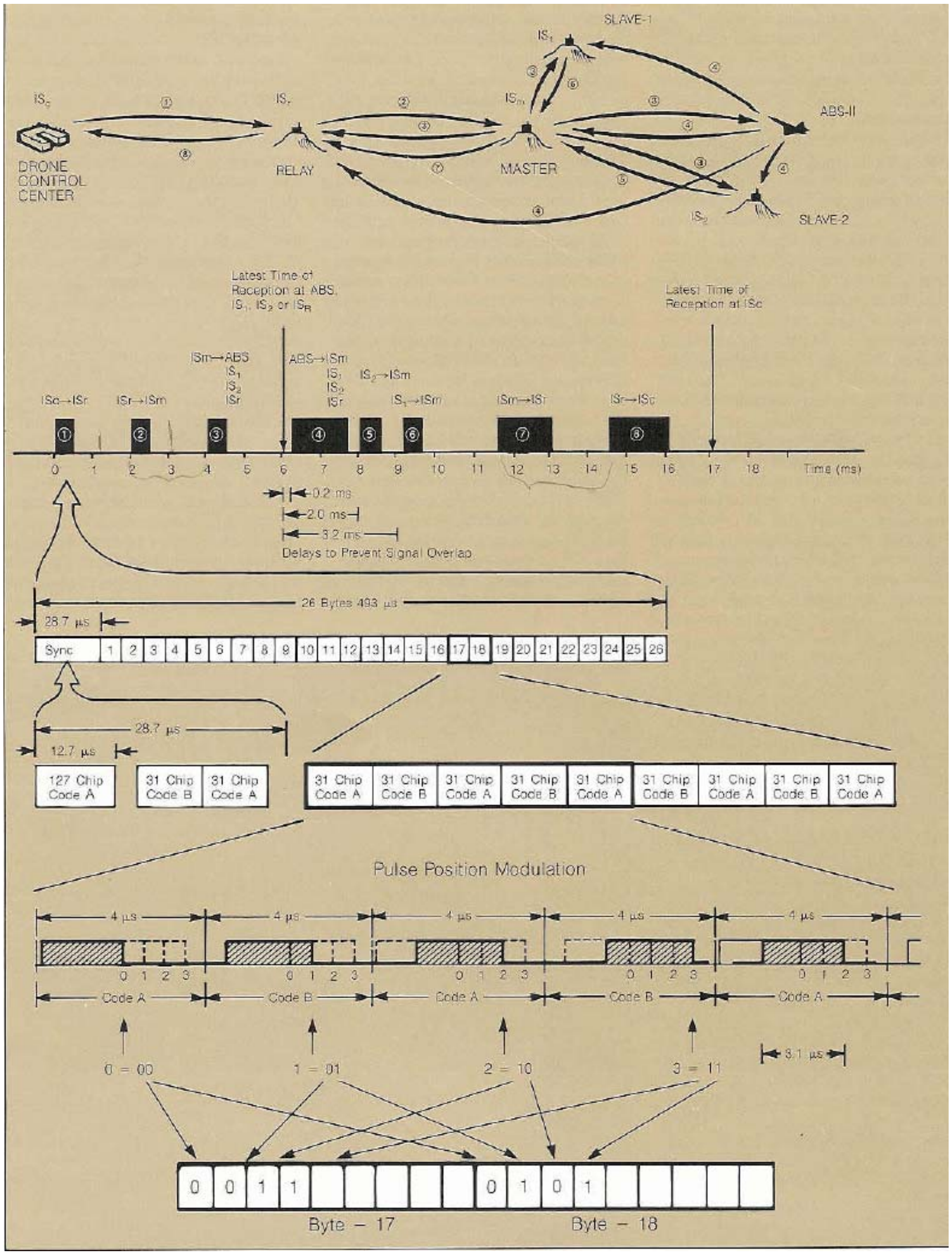
Slaves broadcast a message to the Master at the end of fixed delays. The delays are unique to each ground station. The message contains the contents of its time-of-arrival counter, which holds the time-difference-of-arrival between the receipt of the start of the uplink message (synchronization) from the Master and downlink messages from each target.

The Master broadcasts a message addressed to the Relay. The message contains the telemetry data received from the target(s), Master's TOA(s) and status, and the slaves downlinks.

The Relay broadcast the downlink messages to the ISc. The message contains the information from the Master's message plus the TOA(s) measured at the Relay, if commanded to take TOA(s). At the end of its commanded delay, the ISc passes the contents of the downlink message back to the central processor, completing the data link cycle.

Data link stations are designed so that a station receiving a valid message addressed to it will always transmit an appropriate message in response, whether or not other participating stations respond correctly. This means that every uplink message produces a corresponding downlink message to the central processor. The time-of-arrival and the telemetry data, the downlink message also contains a number of flags. These flags monitor the overall data link performance.

In addition to master, relay, and slave function, ground stations shall also respond to the Tracking Pod uplink. The normal method of calibrating sites is to send a tracking pod uplink to one ground station while using four other sites to track it as a target.



Data Link Waveform

DFCS data link employs a bi-phase coded pulse-position-modulation spread spectrum, RF waveform (see fig 1) with error correction features as the key to reliable performance. A message starts with a synchronization preamble consisting of three unique pulses, one 12.7 microseconds (127 chip code) and two

3.1 microseconds (31 chip code) in length. The 127-chip code performs the actual synchronization while the two 31-chip codes A and B are used to establish signal acceptance level criteria as a safeguard against multipath.

Data is transmitted by alternating the two A and B codes in one of four possible positions (PPM) at four microseconds per code. Those four possible positions correspond to four possible binary numbers (00, 01, 10, 11). The first A code yields the first bits of two nine bits bytes (eight plus parity). The next B code yields the second bits in each of the two bytes, and so until nine A and B codes have produced 18 bits that form two bytes plus parity.

Data Link Accuracy

DFCS in a four-station solution provides horizontal tracking accuracies of about ± 12 feet RMS in the X, Y-axis and ± 40 feet RMS in Z (height). This is repeatable from target to target and mission to mission. DFCS navigation solution is dependent on two factors: data link geometry and the distance measuring accuracy of the data link ground stations

DFCS Ground Station Capabilities

Each Ground Station (GS) shall be capable of supporting DFCS uplink and downlink messages at 512 words per 100 millisecond (msec) time frame. Current ground stations broadcast at 36 microseconds per word, which is equivalent to 18.4 milliseconds per 512 words.

The DFCS GS shall be designed for exterior and interior use with weather sensitive components shielded from weather. The GS shall operate as a slave, relay, master or ISc at WSMR. The GS shall provide the capability to time-of-arrive (TOA) measurements and controllable interval counters for message routing control. The duty cycle shall not exceed 20% as defined as 20msec maximum message length per 100 msec time frame.

DFCS GS Requirements

Quantities:

The delivery of GS shall be no less than ten (10) and not to exceed 20 units total .

Message Protocol

Messages are defined in Appendixes A. DFCS and Gulf Range Drone Control System (GRDCS) have similar message structures. WSMR variations from the GRDCUS format are defined in Appendix B

Warm-up Time

The GS shall be able to transmit or receive a DFCS message five (5) minutes after a power up from a cold start

Power on Reset

The GS shall be able to perform a power on reset in less than one second.

Operational Power

The GS shall operate off 115V AC, 60Hz, single-phase power source and 24V DC.

Transmitter

915 Mhz spread spectrum, bi-phase coded, pulse position modulated transmitter at +53 dBm minimum (+56 dBm desirable)

20% duty cycle per 100 mSec time frame

100 mSec update rate (max)

Frequency stability at 1 PPM @ -20 ^{o} C to +40 ^{o} C

Receiver

915 Mhz @ -90 dBm minimum (-96 dBm desirable)

Test points for Log Video

Data & Synch SAW

Input and Output Impedance

50 ohms nominal, 1.5 : 1 VSWR maximum

Operation Temperature and Environmental Conditions

The operation GS shall be able to withstand temperatures of -10°C to +40°C with no degradation of function.

Time of Arrival (TOA) Counter

24 bit time-of-arrival counter, which holds the time-difference-of-arrival between the receipt of the uplink message from the Master and downlink messages from

the target. The TOA counter shall have a ±8.33 nanosecond accuracy. The clock stability for the TOA counter shall be ± 0.5 PPM or less

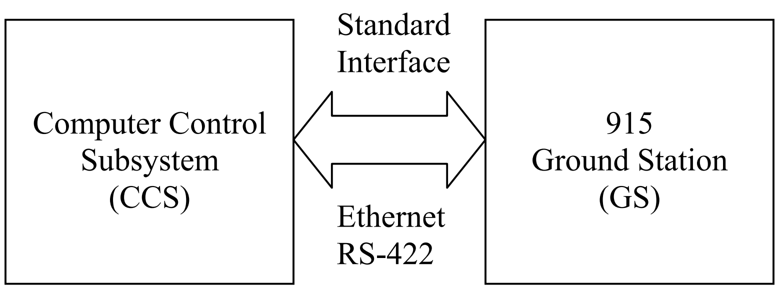
Interval Timer

The interval timer controls the response time of the GS. The response time is the delay between the GS RF message reception and its transmitted response to that message. The Lest Significant Bit (LSB) is 1.0 microsecond and is synchronized to the uplink message with a tolerance of ±8.33 nanosecond. The interval time shall be user selected.

GS Interface

The GS for interfacing with the central processor shall support an Ethernet and a RS-422. These interfaces will not have to work simultaneously. The Ethernet interface shall support TCP-IP and UDP protocols.

Expected Communication Between CCS and 915 Ground Station



Message Format between CCS and GS.

FIELD	DATA TYPE	DESCRIPTION
Size	16 bit integer	Size of message.
SeqNum	16 bit unsigned integer	Echoed back to CCS on reply.
CCSNum	8 bit unsigned integer	ID of commanding CCS (not used by GS).
Command	8 bit unsigned integer	See commands below.
Unused	32 bits	
Data	1024 bytes of data	Uplink or other command data.

Table 1. CCS to GS message format.

FIELD	DATA TYPE	DESCRIPTION
Size	16 bit integer	Size of message.
SeqNum	16 bit unsigned integer	Echoed back SeqNum from CCS command message.
DLINum	8 bit unsigned integer	GS ID number.

Status	8 bit signed integer	Error Status (see below).
Data	2048 bytes of data	Downlink or command response.

Table 2. GS to CCS message format.

Commands

Command	Description
Uplink	Transmit uplink data and return downlink data on command reply.
CCSHealth	Reply with Status = -3.

Other commands will exist for unit configuration and diagnostics.

Status

Status	Description
0	No error
1	Unable to transmit data.
2	Unable to receive data.
3	Command Unknown.

Options
These features shall be priced as options to the DFCS Ground Station.

Signal Quality Measurement

> The unit shall generate a 4-bit value that is proportional to the received signal strength after the Intermediate Frequency stage of the receiver

All Ethernet commands are up-linked to GS in UDP packets on port 1498, and command response downlinked on port 1499.

TCP/IP configuration should be done via RS-422 by similar command format on RS-422 port.

Message format is the same for both RS-422 and Ethernet ports.

The implementation of the complete WSMR and GRDCS message protocol.

APPENDIX A ------ GRDCUS DATA LINK FORMAT for information only

Appendix a

Datalink Message Format Specification Reference Guide

USAF 96th Communications Group
Special Scientific Projects Office
Eglin AFB, Florida 32542

Document Control Number: GRDCS-DLM-046
Publication/Revision Date: 09/23/2002

Revision Sheet

Revision Number	**Date**	**Brief Summary of Changes**
[Dev number] xx.x	*DD-MMM-YYYY*	*Include SIR xxx / Task xxx, and Task Title.*
45.0	30-Aug-2000	SIR 241 / Task 501 - Shooter, Other Altitude Processing
46.0	18-Apr-2002	SIR 350 / Task669 QF-4 AFCC 6.5 Upgrade
47.0	23-Sep-2002	SIR 372 / Replace GRDCS HTML Documents with PDF Files

Review History

SIR xxx / Task xxx	Reviewed By	Date Reviewed	Comments
SIR xxx / Task xxx	*Name 1 / Name 2*	*DD-MMM-YYYY*	*Include a brief description of changes and the applicable chapter filename.*
SIR 241 / Task 501	J. A. Smith	30-Aug-2000	Update the DLM to accommodate the additional TM groups defined for the GRDCS II pods in dlm2_vfu.html and dlm3_vfd.html.
SIR 350 / Task 669	S. Holmes	17-Apr-2002	Update Appendix A for "No Air Data" and "Message Update" DIC's and PRC's. Update Appendix B - DIT 3 Spared and DIT 79 assigned Tail Hook Down.
SIR 372	M. Haynes	04-Oct-2002	Modified to utilize autonumbering for figures and tables, and corrected minor typographical errors.

Chapter 1
Introduction

The datalink message format specified in this manual is used by datalink elements of the Gulf Range Drone Control System (GRDCS) as the message format for "real-time" radio message transfer. Datalink elements include the Datalink Subsystem (DLS), the Flight Termination Transponder (FTT), and a computerized control facility for tracking and/or controlling of drone vehicles on either Eglin or Tyndall AFB's land and water test ranges. Other subsystem elements also utilize the datalink message format for tracking and/or control. They are listed below:

- Signal Processor Vehicle Interface (SPVI) subsystem,
- Shooter (Tracking Pod) subsystems,
- Global Positioning System (GPS Pod) subsystems,
- Datalink Unit (DLU) subsystems (for ground sites),
- Tank Tracking Unit (TTU) subsystems, and
- Target Remote Control (TRC) subsystems (for ground based drone vehicles).

In addition to the Central Control Facility (CCF), in building 380 at Eglin AFB, Florida, drone missions can also be controlled by the Range Control Facility,(RCF) in building 1277 at Tyndall AFB, Florida.

Scope

This specification guide defines the datalink message formats for radio frequency communications between ground control computers, Datalink Subsystems, and other subsystem elements of the Gulf Range Drone Control System and is divided into the following four sections.

Section 1) Introduction.
Section 2) Variable Format Uplink (VFu) Message.
Section 3) Variable Format Downlink (VFd) Message.
Section 4) Appendices.

Important: This user's reference guide is intended for individuals who are comfortable with the IBM RS/6000 computer system, the IBM AIX/6000 operating system, the IBM AIX XL FORTRAN Compiler/6000, and the Visual (Vi) editor.

Required System Capabilities

- The system *must* provide for "hard-wire" datalink message capabilities between the *first* Interface Slave relay (ISr) and the ground control computer. The ISr contributes a message relay function as well as a clocking station function. The first ISr is the DLS which is directly interfaced to the IBM RS/6000 series ground control computer (called the Interrogator co-located (ISc)).

- The system *must* simultaneously control a mix of sub-scale and full-scale drone vehicles either individually or in a formation.

- The system *must* be capable of launching and recovering all drone vehicles in "automatic" mode and maintaining control of them throughout the performance of high energy (G-force) maneuvers.

- The system *must* acquire simultaneous Time Space Position Indication (TSPI) data on Shooter aircraft and Missiles as well as the drone target vehicles.

- The system *must* provide the datalink capability for selective Range Safety flight termination (self destruct) of both drone target vehicles and missiles.

- The system *must* provide accurate position and velocity tracking data for up to ten tanks operating simultaneously on the Eglin test range (B-70) in support of the Joint Service Tactical Aerial Reconnaissance System (JSTARS).

Implementation History

In 1975, International Business Machines (IBM) Federal Systems Division was selected by the US Army's White Sands Missile Range (WSMR), New Mexico to design and develop the Drone Formation Control System (DFCS). The system went operational in February of 1977 with IBM personnel as the on-site operations and maintenance contractor. The DFCS currently tracks and controls the Firebee 34S, the QF-106 and the QF-4 drone aircraft types flying over WSMR airspace and tracks and controls the M-47 drone tank vehicles on the WSMR ground range.

The current GRDCS/GMCS datalink message format is an upgrade in system capability and capacity and is also hardware compatible with the datalink equipment in use by the DFCS and the Multiple-object Tracking and Control System (MTACS), located in building 380 at Eglin AFB, Florida. Integration of the hardware and software for the QF-100 drone type, (using the GRDCS datalink message format), was completed in December of 1987. At that time, the operational management of GRDCS was given to the Weapons Evaluation Group (WEG) at Tyndall AFB, Florida, for use in weapons development evaluation, (i.e., the Advanced Medium Range Air-to-Air Missile (AMRAAM)). Hardware and software modifications for controlling the MQM-107 sub-scale drone aircraft type were developed and test and evaluation flight missions to incorporate "automatic" Launch, Flight, and Recovery phases were completed in August of 1988. Other projects include the implementation of the QF-4 drone aircraft type and testing of the Global Positioning System (GPS) using airborne participants.

The current MTACS went operational in October of 1982 and is used to track and control the M-47 drone tank vehicles on Eglin AFB's B-70 ground range. This system uses the Eglin AFB designed datalink elements (DLU, TTU, and TRC) and the modified GRDCS software to precisely obtain ground vehicle position and velocity data. The Joint Service Tactical Aerial Reconnaissance System (JSTARS) project utilized MTACS for evaluating the Synthetic Aperture Radar System aboard an E-8A type aircraft during 1989 and the Joint Advanced Distributed Simulation (JADS) project used "real-time" GPS data from MTACS in 1996 to evaluate simulated missile tracking capabilities in a three dimensional virtual reality environment.

Datalink Message Description

The GRDCS/GMCS datalink is a multi-function command, control, and tracking system for the over-water test areas of the Gulf Range. The software consists of three subsystems which are known as the Control Subsystem, Input/Output Subsystem, and Console Subsystem. The figure below is intended as an overview of datalink message processing within the GRDCS/GMCS system.

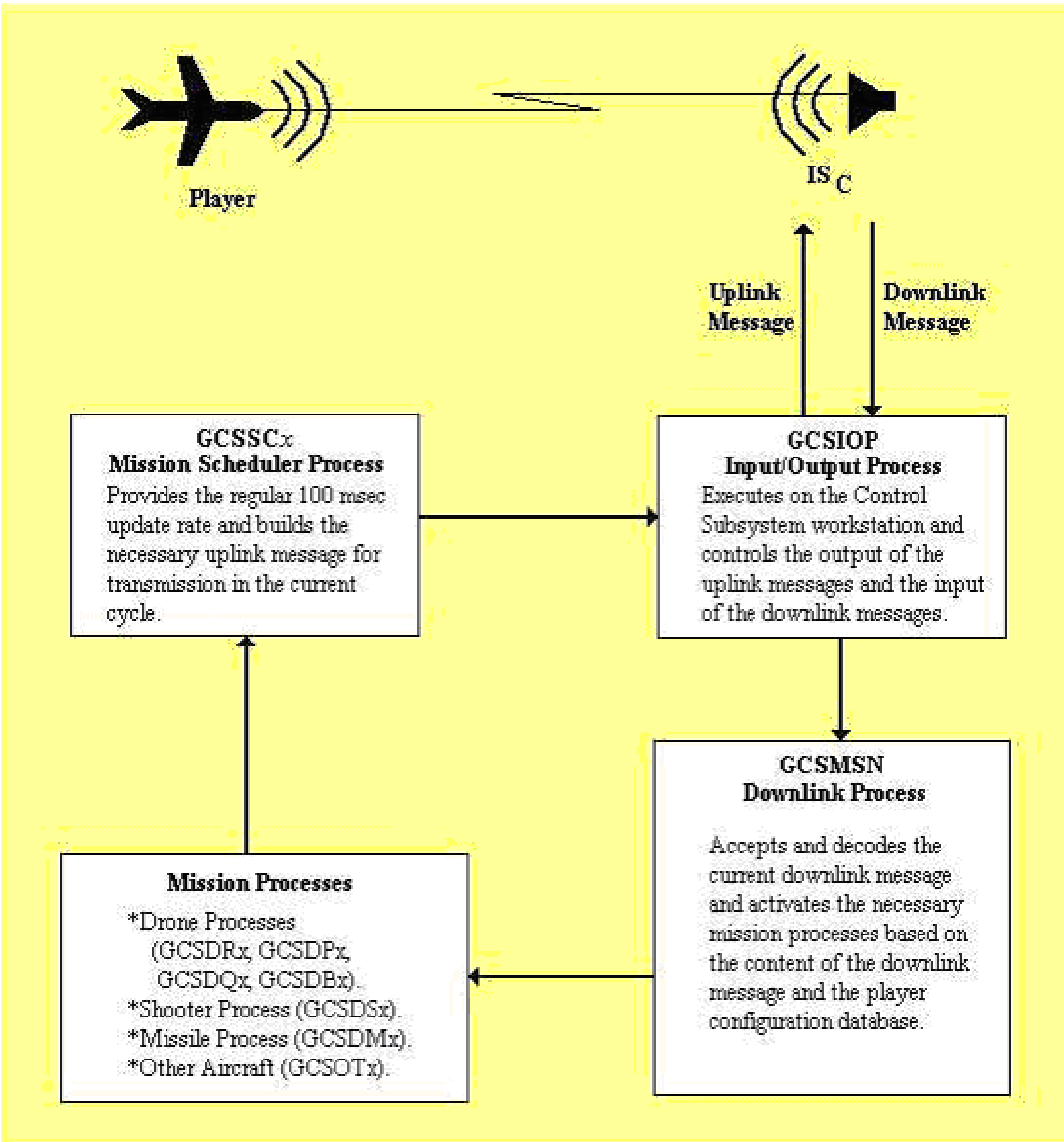


Figure 1 GRDCS/GMCS Uplink/Downlink Message Processing

The datalink system satisfies the following functional requirements:

- The system provides airborne drone target presentation for air-to-air missile firing missions conducted over the Gulf Range, including drone flight termination.
- The system acquires tracking data on DLS, FTT, and SPVI equipped mission participants and provides this data to the mission control facilities.
- The system provides an "over-the-horizon" capability for drones and shooters by utilizing airborne platforms (MU-2 aircraft types) as system clocking stations.
- The system provides a datalink for the exchange of GPS information between ground based and airborne mission participants.
- The system provides a datalink between Range Safety control and the "in-flight" missile termination subsystems.

Datalink Message Sequence

The system message traffic, beginning with the "ground control computer to ISc" message and ending with the "ISc to ground control computer" message, is one datalink message sequence. Up to three datalink message sequences can be generated by the system every 100ms. These messages are used to track and control participants within the system and are also referred to as "tracking" messages.

There are four types of tracking messages in the system:

- Drone 1 message (D1),
- Drone 2 message (D2),
- High Flier message (HF1/HF2), and
- "Other" message (OT1/OT2/OT3/OT4).

> **Note:** Drones can *only* be enabled in the **D1** and **D2** message buffers. Platforms, Shooters, Missiles, and Other Aircraft participants must be distributed among the **HF** and **OT** message buffers based upon mission tracking requirements.

The Master station is the key player in *all* message sequences. After receiving the uplink message from the ISc, it will broadcast the message to all other mission participants (Drones, Beacons, Slaves, etc.) and provide them with their delay value (in half millisecond increments), with which they are to wait before transmitting their response. After broadcasting the message, the Master will transmit one word messages to the FTT datalink units (if applicable). The Master will collect each participant's response, format the entire message, and transmit it downlink to the ISc. If desired, up to five Relay stations can be used between the ISc and Master stations to provide "over the horizon" tracking capabilities.

A datalink message sequence consist of multiple datalink messages. One message sequence can *distribute* command data to Drones and Missiles (uplink phase) and *collect* status information from Drones and Missiles (downlink phase). The very same datalink message sequence can downlink precise clocking measurements (TOAs), which are necessary when computing TSPI for all mission participants.

The *first* message in a datalink message sequence is transmitted from the ground control computer (or ISc which can also play the role of an ISm) to the first Relay (ISr). This message contains station addresses used to identify mission participants and define their functions and command information for all datalink elements. The ISr then transmits the message on uplink (via the datalink waveform) with the same format.

The *last* message in a datalink message sequence is transmitted from the first Relay (ISr) to the ground computer (ISc). This downlink message contains status information (TOAs and telemetry data) from all mission participants.

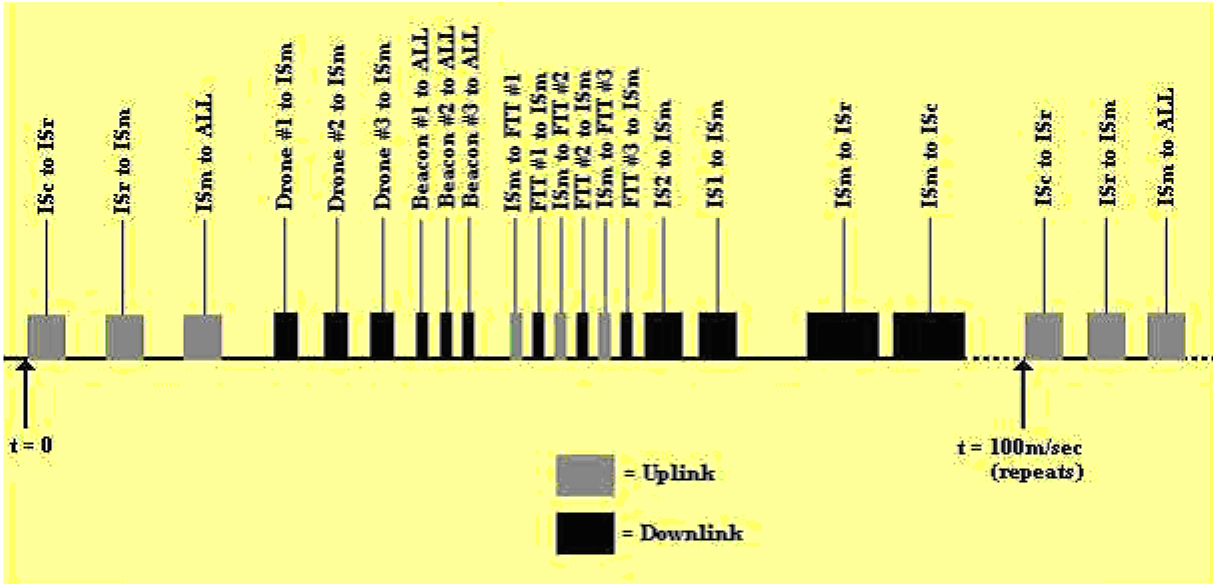


Figure 2 GRDCS/GMCS Datalink Message Sequence

TABLE 1 Common Datalink Messaging Sequence

Sequence Number	Description
1)	The Master's transponder receives an uplink message from the ground computers via the ISc and Relays (more on this below).
2)	The Master's transponder transmits an uplink message to the Drone and resets its TOA clock.
3)	Each Slave's transponder receives the transmitted messages and resets their own TOA clock. The Slaves perform no other action with this message.
4)	The Drone's transponder receives the message and performs the actions required by the commands, in the Drone Frame portion of the message.
5)	The Drone's transponder gathers telemetry (TM) data from its aircraft systems and formats a downlink message. It transmits the downlink message back to the Master, after waiting for a period of time specified in the uplink message (the Drone's delay value).
6)	The Slaves receive the transmitted Drone downlink message and sample their TOA clock. The time difference, from reset to sample, is known as the time-of-arrival (TOA) time.
7)	The Master receives the Drone downlink and samples its own TOA clock.
8)	Slave 1, after waiting for a period of time specified in the uplink message (the Slave 1 delay), transmits to the Master a downlink message containing the TOA data it recorded. Each TOA is referenced to a datalink unit, in the object being clocked, via the datalink unit address.
9)	Slave 2, after waiting for a period of time specified in the uplink message (the Slave 2 delay), transmits to the Master a downlink message containing the TOA and address data it recorded.
10)	The Master combines *all* of the downlink messages it has received into one large message and transmits the downlink message back to the ground computer, via the ISc, after waiting for a period of time specified in the uplink message (Master delay).

The above sequence of steps describes the simplest possible tracking scenario. In an actual "live" mission, a single message may track more than one object. The message transfer between the Master and the ground computer is also somewhat more complex than stated above and is explained further in the note below.

> **Note:** Ground stations interface directly with the ground computer. The uplink message transmitted from the ground computer *must* go directly to an ISc. The downlink message transmitted to the ground computer *must* come directly from an ISc. All messages to/from the ground computer *must* pass through an ISc. If the ISc is itself the Master, in a tracking message quad, the ISc/Master transmits data directly to/from the ground computers. If the ISc is *not* used as the Master (as is often the case), then the uplink message transmitted from the ground computer goes to the ISc, which then retransmits it to the Master. Conversely, the downlink message transmitted from the Drone to the Master goes to the ISc which in turn passes it on to the ground computer.

Datalink Unit Address Conventions

All station addresses are nine bits in length and are configured by switch settings (or jumper wires) on their processors. These settings could be any value from zero to 511 decimal.

The normal practice is to use the datalink unit's serial number as the address. However, because different types of datalink units produced may have similar serial numbers, the following address conventions, listed in the table below, have been adopted for GRDCS/GMCS participants.

TABLE 2 Datalink Unit Address Conventions Overview

Datalink Unit Type	Valid Address
FTT	Addresses 1 through 39, shooter pods.
WRTTM	Addresses 40 - 150, missile warhead replacement package.
SPVI	Addresses 151 - 255, Sub-scale targets, MQM-107 and BQM-34A.
DLS	Addresses 256 - 299, ISc and clocking stations.
SPVI	Addresses 300 - 509, Full scale aerial targets, QF-106 and QF-4.
TTU	Address 32 *plus* the datalink unit's serial number,

	MTACS asset.
DLU	Address 64 *plus* the datalink unit's serial number, MTACS asset.

Note: The following rules apply to the address conventions above.

- The most significant 8 bits *cannot* consist of all ones. (That format is reserved for the high-order byte of the message length work.)
- Addresses 0, 510, and 511 are excluded.
- Address 280 is reserved for the ISc.

Related Documentation

The following documents provide additional information on some of the topics discussed in this manual. These documents are *not* required, but may be helpful.

- DFCS Software Requirements Document, IBM #75W-00188.
- DFCS Datalink Format Specification, IBM #75-L36-032.
- DFCS Airborne Subsystem (ABS II) Specification.
- Statement of Work: Flight Termination Transponder (FTT), TF-81-0104.
- Statement of Work: Datalink Subsystem (DLS), TF-83-0008.
- Datalink Support (DR11) User's guide.
- System Software User's Guide.
- System Programmer User's Guide.
- Console Commands User's Guide.
- Development System (GDS) User's Reference Guide.

Chapter 2
Variable Format Uplink (VFu) Message

The variable format uplink message begins with a message length word which defines the overall length of the message followed by the message header frame which contains the message type, mode, clocking station addresses and their response delay values. The clocking stations consist of the ISc (or ISr), ISm, IS1 and IS2.

The ISm is the Master station of the datalink messaging sequence. The ISm distributes the uplink message *to* all participants, functions as a clocking station, and collects the downlink messages *from* all participants which are then downlinked to the Control Subsystem workstation.

The IS1 (Slave #1) and IS2 (Slave #2) perform as clocking stations. All station addresses are nine bits in length. The clocking stations are located either at ground sites or in manned aircraft flying in proximity to the active mission area of the Gulf Range. The "other" aircraft stations in this type of configuration are also known as airborne Platforms or High Fliers.

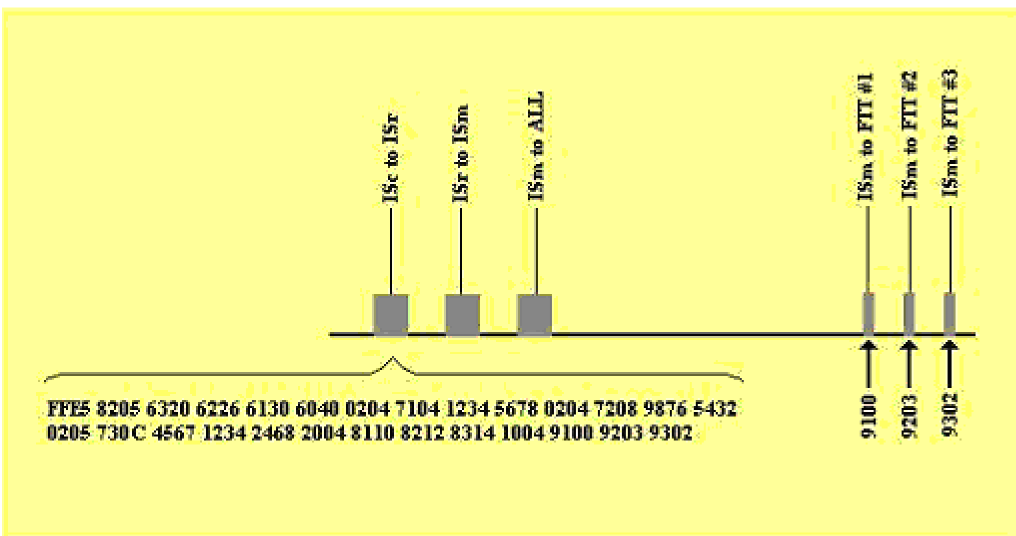


Figure 3 Sample – Variable Format Uplink (VFu) Message

Sample - Variable Format Uplink (VFu) Message

FFE5 8205 6320 6226 6130 6040 0204 7104 1234 5678 0204 7208 9876 5432
0205 730C 4567 1234 2468 2004 8110 8212 8314 1004 9100 9203 9302

FFE5 This is the overall length of the variable format uplink message.
Note: This is a two's complement hexadecimal number of the message length in words (i.e., FFE5 = 27 words).

8205 The **82** symbolizes an uplink type message directed to the *last* Relay.

- If the mode for this message were an **81**, it would dictate that this is a message directed toward the Master station. The remainder of the message would be identical to the preceding message.
- If the mode for this message were an **80**, it would dictate that this is the Master station's broadcast message to *all* participants. The remainder of the message would be identical to the preceding message.

The **05** designates the message header as being 5 words long.

6320 The Slave #2 (IS2) address is 63, and its associated time-out value is 20.

6226 The Slave #1 (IS2) address is 62, and its associated time-out value is 26.

6130 The Master (ISm) address is 61 and its associated time-out value is 30.

6040 The Relay station between the control facility and the Master is address 60 and its associated time-out value is 40.

0204 The 02 designates that the following frame is a Drone type frame which is 4 words long.

7104 The Drone #1, (DRN1), address is 71 and its associated time-out value is 4.

1234 This is a word of commands for the drone to act upon.

5678 This is a second word of commands for the drone to act upon.

0204 The 02 designates that the following frame is a Drone type frame which is 4 words long.

7208 The Drone #2 (DRN2) address is 72 and its associated time-out value is 8.

9876 This is a word of commands for the drone to act upon.

5432 This is a second word of commands for the drone to act upon.

0205 The 02 designates that the following frame is a Drone type frame which is 5 words long.

730C The Drone #3 (DRN3) address is 73 and its associated time-out value is 12.

4567 This is a word of commands for the drone to act upon.

1234 This is a second word of commands for the drone to act upon.

2468 This is a third word of commands for the drone to act upon.

2004 The 20 designates that the following frame is a Beacon type frame which is 4 words long.

8110 The 1st Beacon (BCN1) address is 81 and its associated time-out value is 10.

8212 The 2nd Beacon (BCN2) address is 82 and its associated time-out value is 12.

8314 The 3rd Beacon (BCN3) address is 83 and its associated time-out value is 14.

1004 The 10 designates that the following frame is an FTT type frame.

9100 The 1st FTT address is 91. The 00 commands it into "track" mode.

9203 The 2nd FTT address is 92. The 03 commands it to fire the destruct package.

9302 The 3rd FTT address is 93. The 02 commands it into "arm" mode.

Message Content

A GRDCS/GMCS VFu message *must* begin with the message length word followed by the message header frame. All other message frames are optional.

Message Frames

Subsets of data words (sixteen bits) associated with a particular drone type or group of players is usually referred to as a "frame". The following applies to VFu message frames:

- The message can contain *n* number of frames following the message length word.
- The message frames may be in any order within the message.

However, some exceptions to the implementation defined for GRDCS/GMCS are:

- The Drone message frame(s) follow the Message Header frame in the D1 and D2 tracking messages.
- The Beacon message frame(s), when present, follow the Message Header frame in the High Flier (HF1 and HF2) tracking messages.
- The Shooter (or Tracking Pod) frame, when present, is followed by the GPS Pod frame, when present, which is followed by the FTT frame, when present. They are included in either the HF1/HF2 messages or in the OT1-OT4 messages.

Reference the following figure for VFu message frame ordering.

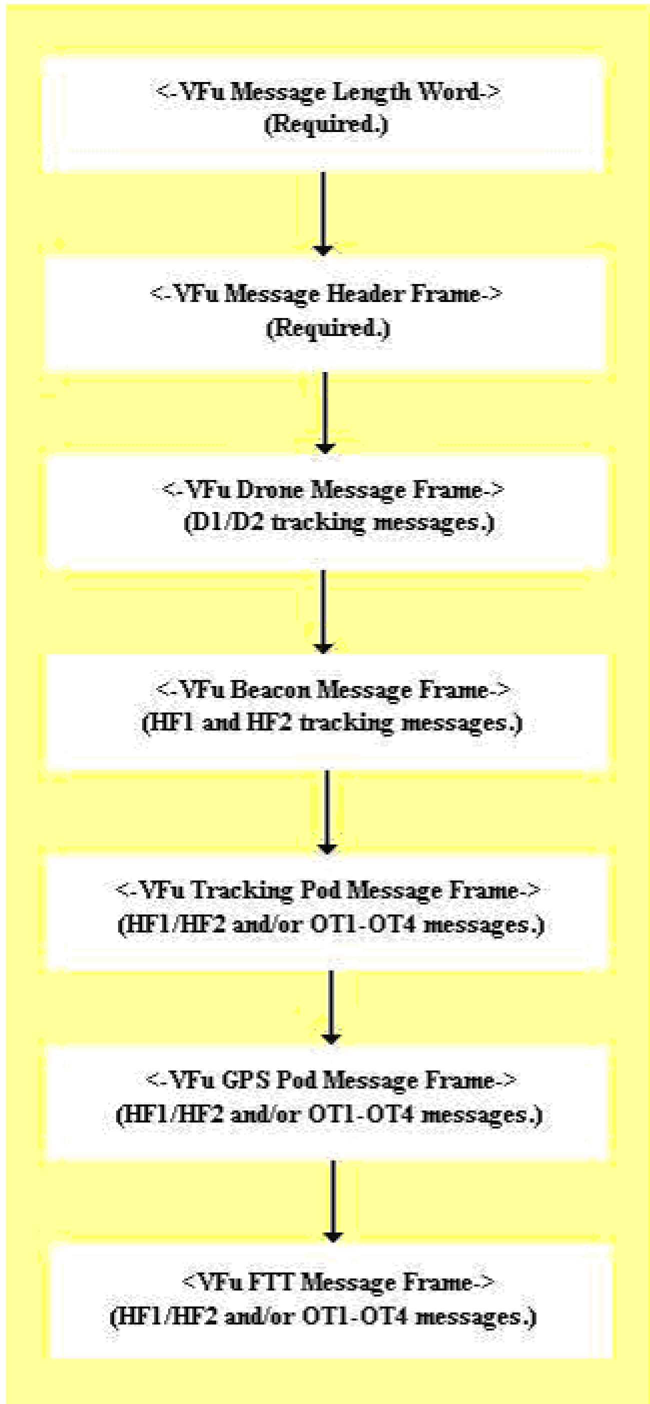


Figure 4 VFu Message Frame Ordering

Message Length Word

The first word of the VFu message defines the overall length of the message in sixteen bit words. The ground computer generates a positive uplink word count which is converted to a negative number (two's complement) before transmission to the participant players. This helps to differentiate between a broadcast message to all participants and a one word message exchanged between the Master and a Missile player with an FTT message frame.

VFu Message - Message Length Word - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
ML	1	aaaa	aaaa	llll	llll

VFu Message - Message Length Word - Content

Frame Field	**Description**
aaaaaaaa	Eight bits (all ones). This byte signals all stations to analyze this VFu message separate from an FTT one word VFu message.
llllllll	Eight bits representing the total message length in sixteen bit words (expressed as a negative two's complement number).

Message Header Frame (8xxx)

The message length word *must* be followed by the message header frame. The message header frame defines the message type, mode, and participant addresses and their associated delays.

VFu Message - Message Header Frame - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
MH	1	ffff	oooo	hhhh	hhhh
MH	2	2222	2222	2ddd	dddd
MH	3	1111	1111	1ddd	dddd
MH	4	mmmm	mmmm	mddd	dddd
MH	n	rrrr	rrrr	rtww	wwww

VFu Message - Message Header Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (1000 binary).
oooo	The message frame "mode" field. This field, as it originates from the ground control computer, *must* equal the length of the message header in sixteen bit words minus 3 (e.g., For a six (two Relay) word header, this field would be 0011 binary). Each station in the uplink chain will decrement this field *before* re-transmission. The Master is the *last* link in the uplink chain and will transmit this field as all zeros for its broadcast message to all participants.
hhhhhhhh	This eight bit field is the header length field in sixteen bit words.
222222222	The Slave 2 (IS2) address for this VFu message sequence.
ddddddd	The in-sequence time-out delay for the station whose address is contained in the most significant nine bits of this sixteen bit word.
111111111	The Slave 1 (IS1) address for this VFu message sequence.
ddddddd	The in-sequence time-out delay for the station whose address is contained in the most significant nine bits of this sixteen bit word.
Mmmmmmmmm	The Master (ISm) address for this VFu message sequence.
ddddddd	The in-sequence time-out delay for the station whose address is contained in the most significant nine bits of this sixteen bit word.
rrrrrrrrr	The Relay(s) (ISr) for this VFu message sequence. • If *no* Relay station, this field and its associated delay field (w) will be absent. • If *multiple* Relay stations (maximum of 6), there will be multiple "r" fields with their associated delay values. • If the first ISr is to perform as the Master, this field will be deleted and the ISr's address will be inserted into the "m" field. The ISr's address is located in the *last* word of the message header.
t	• If a value of one (1), this field commands the ISr (whose address is contained in the most significant nine bits of this sixteen bit word) to perform as a clocking station and take TOA measurements. • If a value of zero (0), the ISr will *only* perform as a data relay station.
wwwwwww	The in-sequence time-out delay for the ISr whose address is

	contained in the most significant nine bits of this sixteen bit word.

Drone Message Frame (00xx)

The GRDCS/GMCS aircraft drone vehicles are chiefly used as targets for weapon systems evaluation testing. Each drone message frame contains the necessary command data to control one drone vehicle. The VFu message can contain *n* number of drone message frames. Each drone message frame consists of the frame length, mode, and command data for the addressed drone type.

VFu Message - Drone Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
Dn	1	ffff	mmmm	ttll	llll
Dn	2	aaaa	aaaa	aedd	dddd
Dn	3	pppn	ncxx	ssss	ssss
Dn	n	dddd	dddd	dddd	dddd
Dn	n	ssss or gggg	ssss or gggg	ssss or gggg	ssss or gggg

Note: The drone message frame can be used to track and control M-47 tank drone vehicles using MTACS. If the drone vehicle is equipped with a GPS subsystem, GPS data may then be uplinked.

VFu Message - Drone Message Frame - Content

Frame Field	Description
ffff	The message frame "type" field (0000 binary).
mmmm	The message frame "mode" field. Valid Modes: 0000 Command and Control. 0001 Track.
tt	The designated drone vehicle type. Valid Drone Types: 00 = QF-4 01 = MQM-107B/D/E 11 = BQM-34A *or* 11 = M-47 (Drone tank vehicle participant in MTACS.)
llllll	The length of this drone message frame, in sixteen bit words.
aaaaaaaaa	The drone vehicle's address.
e	The error flag. Set to one if this message frame contains a data error.
dddddd	The commanded drone delay value.
ppp	The drone's escape option.
nn	The drone's antennae selection command. Valid Antennae Commands: 00 = Go to antenna 0 (QF-106 = Tail; MQM-107B = Top) 01 = Go to antenna 1 (QF-106 = Chin; MQM-107B = Right) 10 = Go to antenna 2 (QF-106 - Split; MQM-107B = Left) 11 = Remain on current antenna.
c	The commanded drone escape value.
xx	The telemetry multiplex group.
ssssssss	**<Spare bits.>**
dddd dddd dddd dddd	Drone dependent commands.
ssss ssss ssss ssss *or*	**<Spare bits.>**
gggg gggg gggg gggg	For drone vehicles equipped with a GPS Pod subsystem, this field will contain up to 41 words of GPS data. This includes a message header word, data words, and a message checksum word.

Beacon Message Frame (20xx)

The VFu message can contain one Beacon message frame which consists of a frame header and *n* number of words of Beacon message frame data. Each beacon message frame data word contains the address and commanded delay value for one Beacon station participant. The Beacons are located at fixed, known locations and are used to locate the airborne platform participants.

VFu Message - Beacon Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
BH	1	ffff	mmmm	llll	llll
BD	n	aaaa	aaaa	addd	dddd

VFu Message - Beacon Message Frame - Content

Frame Field	Description
ffff	The message frame "type" field (0010 binary).
mmmm	The message frame "mode" field. Valid Modes: 0000 Transponder Mode (binary).
llllllll	The length of the Beacon message frame in 16 bit words (e.g., the Beacon message frame header plus 2 Beacon message frames, 2 Beacon participants, equals a message length of 3).
aaaaaaaaa	The Beacon's address.
ddddddd	The commanded Beacon delay value.

Example:

```
VFu Beacon message frame header and data.
BH 1 0010 0000 0000 0011  (2003)
    Length is 3 words (2 Beacons).  Transponder mode.
BD 1 0000 0001 0000 0011
    Beacon address is 2.  Transpond after a delay of 3.
BD 2 0000 0001 1000 0101
    Beacon address is 3.  Transpond after a delay of 5.
```

Tracking Pod Message Frame (4xxx)

The VFu message can contain *one* Tracking Pod message frame which consists of a frame header and *n* number of words of Tracking Pod data. Tracking Pods are *only* mounted on participants which are required to be tracked (i.e., Shooter aircraft).

> **Note:** The Tracking Pod message frame is also used for tracking TTU's (using MTACS) in M-47 drone tank vehicles.

VFu Message - Tracking Pod Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
TP	l	ffff	GGGG	llll	llll
TP	n	aaaa	aaaa	ae0d	dddd

VFu Message - Tracking Pod Message Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (0100 binary).
GGGG	Telemetry Format Group value. (Indicates which group of A/D 12 bit data words to downlink.) Valid Groups: 0000 Incremental selection of A/D data groups 1-4, but *not* Group 5. 0001 Group 1. Words 1,2,3,& 4. 0010 Group 2. Words 5,6,7,& 8. 0011 Group 3. Words 9,10,11,& 12. 0100 Group 4. Words 13,14,15,& 16. 0101 Group 5. Responds with current firmware version. 0110 Group 6. Spare group. 0111 Group 7. Spare group. 1000 Group 8. GPS Time Sync Data. 1001 Group 9. GPS Pod Status. 1010 Group 10. GPS Navigation Data. 1011 Group 11. GPS SV Status Data. 1100 Group 12. GPS SV Tropo Data. 1101 Group 13. GPS SV Iono Data. 1110 Group 14. GPS SV Track Status. 1111 Group 15. Unused.
llllllll	The length of the Tracking Pod message frame in 16 bit words (i.e., 1 plus the number of Pods being addressed).
aaaaaaaaa	The Tracking Pod's address.
e	Uplink error set by Relay(s) or Master.
0	Zero bit.
ddddd	Delay value of 0-15ms in 0.5ms increments.

Global Positioning System (GPS) HDIS Pod Message Frame (3xxx)

The GPS Subsystem is used to locate MTACS participants equipped with a RAJPO HDIS GPS Pod. The GPS Subsystem tracks players via satellite signals and TOA measurements.

VFu Message - GPS Pod Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
Gp	1	ffff	LLLL	llll	llll
Gp	n	aaaa	aaaa	aeDD	DDDD
Gp	n	gggg	gggg	gggg	gggg

VFu Message - GPS Pod Message Frame - Content

Frame Field	Description
ffff	The message frame "type" field (0011 binary).
LLLL	The number of participants being addressed in this message frame.
llllllll	The length of this GPS Pod message frame in 16 bit words.
aaaaaaaaa	The nine bit address of this participant.
e	The error flag. Set to one if this message frame contains a data error.
DDDDDD	The commanded delay value for this participant.
gggg gggg gggg gggg	The GPS data will vary depending upon the nature of the uplink message. This includes a message header word, data words, and a message checksum word. Reference the *Global Positioning System Gulf Range Drone Control Upgrade System Interface Control Drawings* document for details of the GPS message format.

Flight Termination Transponder (FTT) and WRTTM Message Frame (10xx)

The VFu uplink message may contain one FTT message frame which consists of a frame header and *n* number of words of FTT data. FTT's are *only* installed in participants which require either tracking (i.e., Shooters) or tracking and/or safety destruct capabilities (i.e., Missiles).

> **Note:** Two words are needed for *each* transponder used. The first word, A, has a 9 bit address with a 6 bit delay. The second word, B, repeats the address and contains the control bits required for one FTT equipped player.

VFu Message - FTT Message Frame - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
FH	1	ffff	mmmm	llll	llll
FD	1A	aaaa	aaaa	aedd	dddd
	1B	ssss	sLDD	ssss	ssss

VFu Message - FTT Message Frame - Content

Frame Field	Description
ffff	The message frame "type" field (0001 binary).
mmmm	The message frame "mode" field. Valid Modes: 0000 Sequential Track Mode (binary).
llllllll	The length of the FTT message frame in 16 bit words.
aaaaaaaaa	The nine bit binary FTT address. Each FTT has its own unique address which is the binary equivalent of the decimal serial number of the FTT. **Note:** Unless these address bits are identical to the serial number of the FTT, the FTT will neither respond with a downlink message nor react to the control information contained in an uplink message.
e	The message error bit. If this bit is set to 1 and the address and mode fields are valid for the FTT, the FTT will respond with a downlink message, but will *not* react to the control information within the uplink.
dddddd	The delay value for the Master station to wait before transmitting the one word message to this FTT. This provides an adjustable response time from the FTT, even though the unit itself has a fixed delay time.
L	When reset to 0 (zero), this enables normal resetting of the loss of valid carrier (LOVC) timer in response to a *valid* uplink message. A valid uplink message is one which has the proper address and mode, message error (e), bit "off", and no detected parity errors or erasures.
s	Spare bits.
DD	These bits will control the destruct discrete outputs of the FTT. For these commands to have an effect, they must be contained within a *valid* message. Valid Commands: 00 - Off. 01 - Prearm. 10 - Arm. 11 - Fire. An Off command always deactivates *all* of the destruct discretes. Two consecutive Prearm commands always activate the prearm discrete output and deactivate the arm and fire discrete outputs. To activate the *arm* discrete output, a sequence consisting of at least one

	Prearm command immediately followed by two consecutive Arm commands *must* be recognized by the FTT. This command will also deactivate the fire discrete output, if it has not already been deactivated. To activate the *fire* discrete output, a sequence consisting of at least one Prearm command immediately followed by at least one Arm command immediately followed by <u>four</u> consecutive Fire commands *must* be recognized by the FTT.

Error Handling

As the VFu message is transmitted from station to station, transmission/reception errors are inevitable. The station receiving the message in error will take action according to the position of the error.

Message Header Frame Errors

- If an error occurs in the *first*, *second*, or *fifth* word of the VFu message, the message will be rejected by the intended station and thus the message sequence will fail to progress the message through the uplink stations. (Reference the Message Header Frame section.)
- If an error occurs in the *third* or *fourth* word of the VFu message, that word will be zeroed before re-transmission. The resultant Slave data will be lost.
- If an error occurs in the Relay list *and* the "mode" field is less than or equal to 3, the VFu message will be rejected by the intended station (ISr), thus failing to progress the message through the uplink. Otherwise, the error will be ignored.

Drone Message Frame Errors

- If an error occurs in the *first* word of the VFu Drone message frame, the rest of the uplink message is deleted and the message length field is adjusted accordingly. (Reference the Drone message frame section.)
- If an error occurs in the *second* word of the VFu Drone message frame, the Drone's address word will be set to zeros by that station (Master or Relay), and the uplink error bit will be set.
- If an error occurs in the *third* through the *last* word of the VFu Drone message frame, bit <u>six</u> of the *second* word will be set to one so that the Drone will *not* accept the uplinked commands.

Beacon Message Frame Errors

- If an error occurs in the *first* word of the VFu Beacon message frame, the rest of the uplink message will be deleted and the message length field will be adjusted accordingly. (Reference the Beacon message frame section.)
- If an error occurs in the *second* through the *last* word of the VFu Beacon message frame, the word will be set to zeroes.

FTT Message Frame Errors

- If an error occurs in the *first* word of the VFu FTT message frame, the rest of the uplink message will be deleted and the message length field will be adjusted accordingly.
- If an error occurs in the *second* through the *last* word of the VFu FTT message frame, bit six of the word (error flag) will be set to one so that the transponder will *not* accept the uplinked commands.

Chapter 3
Variable Format Downlink (VFd) Message

The variable format downlink message to the ground control computer contains status information from all mission participants, Time-Of-Arrival data, and telemetry data from Drones, Shooters, and FTT equipped players.

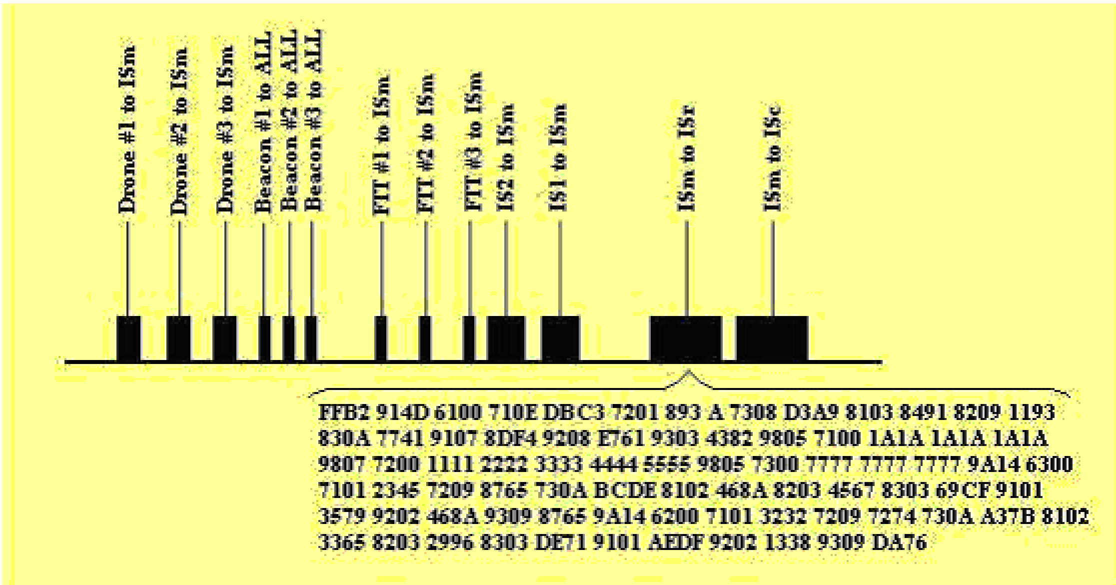


Figure 5 Sample – Variable Format Downlink (VFd) Message

Sample - Variable Format Downlink (VFd) Message

Drone #1 to ISm:	**FFFA 9805 7100 1A1A 1A1A 1A1A**
FFFA	This is the Drone's total message length. Note: This is a two's complement hexadecimal number of the message length in words (i.e., FFFA = 6 words).
9805	The 98 identifies this VFd message as a Drone's message frame. the 05 defines the Drone's frame length.
7100	The transmitting Drone's address is 71. This Drone's internal status is 00.
1A1A	These three words are the Drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc.
Drone #2 to ISm:	**FFF8 9807 1111 2222 3333 4444 5555**
FFF8	This is the drone's total message length. Note: This is a two's complement hexadecimal number of the message length in words (i.e., FFF8 = 8 words).
9807	The 98 identifies this VFd message as a drone's message frame. The 07 defines the drone's frame length.
7200	The transmitting drone's address is 72. This drone's internal status is 00.
1111 to 5555	These five words are the drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc. Note: The amount of VFd data transmitted will depend upon the uplink commands issued and the particular drone "type" which is participating in the mission.
Drone #3 to ISm:	**FFFA 9805 7300 7777 7777 7777**
FFFA	This is the Drone's total message length. This is a two's complement hexadecimal number of the message length in words (i.e., FFFA = 6 words).
9805	The 98 identifies this VFd message as a Drone's message frame. The 05 defines the Drone's frame length.

7300	The transmitting Drone's address is 73. This Drone's internal status is 00.
7777 to 7777	These three words are the drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc.
<u>Beacon #1 to ALL</u>:	**8100**
8100	The address for BCN1 is 81 and its status is 00.
<u>Beacon #2 to ALL</u>:	**8200**
8200	The address for BCN2 is 82 and its status is 00.
<u>Beacon #3 to ALL</u>:	**8300**
8300	The address for BCN3 is 83 and its status is 00.
<u>FTT #1 to ISm</u>:	**9928**
9928	The address for FTT1 is 91 and its status is 28.
<u>FTT #2 to ISm</u>:	**9202**
9202	The address for FTT2 is 92 and its status is 02.
<u>FTT #3 to ISm</u>:	**9902**
9902	The address for FTT3 is 93 and its status is 02.
<u>Slave #2 to ISm</u>:	**FFEB 9A14 6300 7101 2345 7209 8765 730A BCDE 8102 468A** **8203 4567 8303 69CF 9101 3579 9202 468A 9309 8765**
FFEB	This is the Slave's total message length. <u>Note</u>: This is a two's complement hexadecimal number of the message length in words (i.e., FFEB = 21 words).
9A14	The 9A identifies this VFd message as a Slave's message frame to the Master. The 14 defines the Slave's frame length to be 20 words long.
6300	The address for IS2 is 63 and its status is 00.
7101 2345	TOA reading. Address of the participant is 71. TOA reading is

12345.

7209 8765 2nd TOA reading. Address of the participant is 72. TOA reading is 98765.

730A to 8765 The remainder of this Slave's address frame is the TOA list of all of the other participants that it heard. This data is transmitted to the Master which in turn re-transmits the data to the Relay (ISr) and the control facility (ISc).

Slave #1 to ISm: FFEB 9A14 6200 7101 3232 7209 7274 730A A37B 8102 3365
8203 2996 8303 DE71 9101 AEDF 9202 1338 9309 DA76

FFEB This is the Slave's total message length.
Note: This is a two's complement hexadecimal number of the message length in words (i.e., FFEB = 21 words).

9A14 The 9A identifies this VFd message as a Slave's message frame to the Master. The 14 defines the Slave's frame length to be 20 words long.

6200 The address for IS1 is 62 and its status is 00.

7101 3232 TOA reading. Address of the participant is 71. TOA reading is 13232.

7209 7274 2nd TOA reading. Address of the participant is 72. TOA reading is 97274.

730A to DA76 The remainder of this Slave's message frame is the TOA list of all of the other participants that it heard. This data is transmitted to the Master which in turn re-transmits the data to the Relay (ISr) and the control facility (ISc).

ISm to ISr: FFB2 914D 6100 710E DBC3 7201 893A 7308 D3A9 8103 8491 8209 1193
830A 7741 9107 8DF4 9208 E761 9303 4382 9805 7100 1A1A 1A1A 1A1A
9807 7200 1111 2222 3333 4444 5555 9805 7300 7777 7777 7777 9A14 6300
7101 2345 7209 8765 730A BCDE 8102 468A 8203 4567 8303 69CF 9101
3579 9202 468A 9309 8765 9A14 6200 7101 3232 7209 7274 730A A37B 8102
3365 8203 2996 8303 DE71 9101 AEDF 9202 1338 9309

	DA76
FFB2	This is the Master's total message length. Note: This is a two's complement hexadecimal number of the message length in words (i.e., FFB2 = 78 words).
914D	The 91 identifies this VFd message as a Master's message frame. The 4D defines the Master's frame length to be 77 words long.
6100	The address for the station acting as the Master is 61 and its status is 00.
710E DBC3	TOA reading. Address of the participant is 71. TOA reading is EDBC3.
7201 893A	2nd TOA reading. Address of the participant is 72. TOA reading is 1893A. Note: This Master station took TOA counts on seven other stations. These stations are addressed 73, 81, 82, 83, 91, 92, and 93. Each of these stations have a TOA; this TOA is the 20 bits which follow the address.
9805	The 98 identifies this VFd message as a Drone's message frame to the Master.
7100	The address for this Drone is 71 and its status is 00.
1A1A ...	The drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc.
9807	The 98 identifies this VFd message as a Drone's message frame to the Master.
7200	The address for this Drone is 72 and its status is 00.
1111 to 5555	The drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc.
9805	The 98 identifies this VFd message as a Drone's message frame to the Master.
7300	The address for this Drone is 73 and its status is 00.
7777 ...	The drone's downlink telemetry which includes airspeed, altitude, flap position, landing gear, etc.

9A14	The 9A identifies this VFd message as a Slave's message frame. The 14 defines the Slave's frame length to be 20 words long.
6300	The address for this Slave is 63 and its status is 00.
7101 2345	TOA reading. Address of the participant is 71. TOA reading is 12345.
7209 8765	2nd TOA reading. Address of the participant is 72. TOA reading is 98765. Note: The remaining 14 words of this Slave message frame is composed of the addresses and TOA data for seven other stations. This data, along with the preceding six words, comprise this portion of the Master's VFd message.
9A14	The 9A identifies this VFd message as a Slave's message frame. The 14 defines the Slave's frame length to be 20 words long.
6200	The address for this Slave is 62 and its status is 00.
7101 3232	TOA reading. Address of the participant is 71. TOA reading is 13232.
7209 7274	2nd TOA reading. Address of the participant is 72. TOA reading is 97274. Note: The remaining 14 words of this Slave message frame is composed of the addresses and TOA data for seven other stations. This data, along with the preceding six words, comprise this portion of the Master's VFd message.

Note: The ISm to ISc message is identical to the ISm to ISr message. The only difference is that the third byte will be 92 instead of 91.

Message Content

A GRDCS/GMCS VFd message *must* begin with the message length word which is followed by *at least* one Relay or Master message frame. All other message frames are optional.

Message Frames

Subsets of data words (sixteen bits) associated with a particular drone type or group of players is usually referred to as a "frame". The following applies to VFd message frames:

- The message can contain *n* number of frames following the message length word.
- The *first* Relay or Master message frame (in the D1 and D2 tracking messages) can be followed by Relay frames which are again followed by the Master frame.
- The Drone frames (when present) follow the Master frame which are followed by the Tracking Pod frame (when present), which is followed by the GPS Pod frame (when present), which is followed by the FTT frame (when present). They are included in either the HF1/HF2 tracking messages or in the OT1-OT4 tracking messages.
- The Slave frames (when present) are last. They are included in either the D1/D2 tracking messages or in the HF1/HF2 tracking messages.

Reference the following figure for VFd message frame ordering.

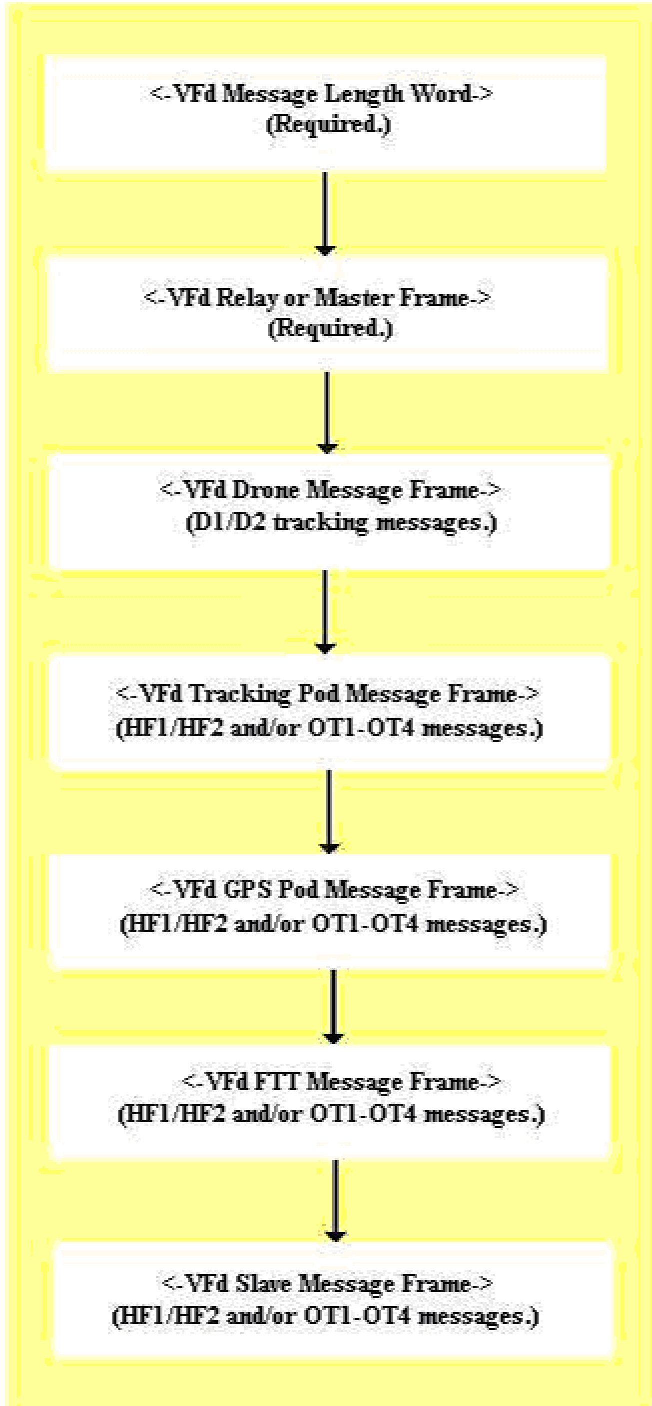


Figure 6 VFd Message – Message Frame Ordering

Message Length Word

The first word of the VFd message defines the overall length of the message in sixteen bit words. The datalink unit generates a positive downlink word count which is converted to a negative number (two's complement) before a transmission between stations.

VFd Message - Message Length Word - Layout

Word	#	msb-	- - - -	- - - -	-lsb
ML	1	llll	llll	llll	llll

VFd Message - Message Length Word - Content

Frame Field	Description
llllllllllllllll	Sixteen bits representing the total message length in sixteen bit words (expressed as a negative two's complement number while being transmitted between datalink stations).

Relay or Master Message Frame (9xxx)

The Relay and/or Master message frames contain the frame type, length, source address, and optional TOA data. If the Master is an airborne platform participant with a GPS Pod, a separate GPS message frame containing the GPS data will be downlinked.

VFd Message - Relay or Master Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
Rn	1	ffff	0000	llll	llll
Rn	2	aaaa	aaaa	asss	ssss
Rn	3	aaaa	aaaa	aytt	tttt
Rn	4	tttt	tttt	tttt	tttt
Rn	n	dddd	dddd	dddd	dddd

VFd Message - Message Length Word - Content

Frame Field	**Description**
ffff	The message frame "type" field (1001 binary).
oooo	The Relay "mode" field. This field represents the first Relay (ISc), as it originated from the ground control computer. Subsequent Relay mode fields will be one smaller than the previous until the Master mode field (0001 binary).
llllllll	This eight bit field is the frame length field in sixteen bit words.
aaaaaaaaa	The source address of the datalink station for this message.
sssssss	The status field associated with the source datalink station. A value of 1: In bit 0, indicates a receive error in the downlink message. In bit 1, indicates a receive error in the uplink message. In bit 2, indicates a power-on-reset (POR). In bit 3, indicates a microwave downlink error. In bit 4, indicates a serial interface error. Note: Bits 3 and 4 relate to the ISc only.
aaaaaaaaa	The address associated with adjacent TOA fields.
y	The validity bit for the current TOA reading. If this bit is 1, this word and the next word will be invalid.
ttttt	Most significant 6 TOA bits associated with the adjacent address field.
tttt tttt tttt tttt	Least significant 16 TOA bits associated with the preceding address field.
dddd dddd dddd dddd	Words Rn 3 and Rn 4 repeated for each system participant for which a TOA measurement is available.

Drone Message Frame (98xx)

The GRDCS/GMCS aircraft drone vehicles are chiefly used as targets for weapon systems evaluation testing. Each drone message frame contains the necessary status information for one drone vehicle. The VFu message can contain *n* number of drone message frames. However, the total length of a Drone's VFd message is limited to 63 words due to the 6 bit message length field.

VFd Message - Drone Message Frame - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
Dn	1	ffff	oooo	TTll	llll
Dn	2	aaaa	aaaa	ass	ssss
Dn	n	dddd	dddd	dddd	dddd
Dn	n	gggg	gggg	gggg	gggg

Note: The drone message frame can be used to obtain status information on M-47 tank drone vehicles using MTACS. If the drone vehicle is equipped with a GPS Pod subsystem, GPS data may then be downlinked.

VFd Message - Drone Message Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (1001 binary).
oooo	The message frame "mode" field (1000 binary).
TT	The designated drone vehicle type. Valid Drone Types: 00 = QF-4 01 = MQM-107B/D/E 11 = BQM-34A *or* 11 = M-47 (Drone tank vehicle participant in MTACS).

llllll	The length of this drone message frame in sixteen bit words. Note: There is a 63 word maximum length for a Drone message frame.
aaaaaaaaa	The drone vehicle's address.
ssssss	The Drone's status bits 0 through 6 as follows: 0 = POR (a power-on-reset has occurred since the last downlink). 1 = Data flag (at Drone on uplink). 2 = Data error (at the downlink station). 3 = Telemetry Format Group. 4 = Telemetry Format Group. 5 = Current antennae position. 6 = Current antennae position. 00 - Antenna 0. 01 - Antenna 1. 10 - Antenna 2. 11 - Malfunction in switch. dddd dddd dddd dddd Drone dependent status. gggg gggg gggg gggg For drone vehicles equipped with a GPS subsystem, this field will vary depending upon the nature of the downlink message. This includes a message header word, data words, and a message checksum word.

Tracking Pod Message Frame (9C05)

Each VFd Tracking Pod message frame contains status and data from one participant being tracked (i.e., Shooter aircraft). The downlink message can contain *n* number of Tracking Pod message frames.

> **Note:** The Tracking Pod message frame is also used for tracking TTU's (using MTACS) in M-47 drone tank vehicles.

VFd Message - Tracking Pod Message Frame - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
PF	1	ffff	oooo	llll	llll
PF	2	aaaa	aaaa	arGG	GRgE
PF	3	JJJJ	JJJJ	JJJJ	KKKK
PF	4	KKKK	KKKK	LLLL	LLLL
PF	5	LLLL	MMMM	MMMM	MMMM

VFd Message - Tracking Pod Message Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (1001 binary).
oooo	The message frame "mode" field (1100 binary).
llllllll	The length of the Tracking Pod message frame in 16 bit words (i.e., 2 plus the number of data words).
aaaaaaaaa	The Tracking Pod's address.
r	Radar altimeter. The value is invalid if *r* is equal to 1.
gGGG	Telemetry Format Group value. (Indicates which group of A/D channels to downlink.)

	Valid Groups: 0000 Group 1. A/D channels 1, 2, 3, & 4. 0001 Group 2. A/D channels 5, 6, 7, & 8. 0010 Group 3. A/D channels 9, 10, 11, & 12. 0011 Group 4. A/D channels 13, 14, 15, & 16. 0100 Group 5. Responds with current firmware version (e.g., J-M bits could have a date of Dec. 5, 1987 @ 2:27 PM expressed in the format 120519871427). 0101 Group 6. Unused. 0110 Group 7. Unused. 0111 Group 8. Unused. 1000 Group 9. GPS Time Sync Data. 1001 Group 10. GPS Pod Status. 1010 Group 11. GPS Navigation Data. 1011 Group 12. GPS SV Status Data. 1100 Group 13. GPS SV Tropo Data. 1101 Group 14. GPS SV Iono Data. 1110 Group 15. GPS SV Track Status. 1111 Group 16. Unused.
R	Tracking Pod reset. Equals 1 if a POR or wake-up timer event.
E	Downlink error set by Relay(s) or Master.
JJJJJJJJJJJ	Radar altitude (up to 2500 ft.) in TM Format Groups 1, 2, 3, & 4.
KKKKKKKKKKKK	Barometric pressure (in HG) in TM Format Groups 1, 2, 3, & 4.
MMMMMMMMMMMM	Interface card temperature (degrees C) in TM Format Group 1 only.

Note: The MTACS Tank Tracking Units (TTU's) only monitor the temperature sensors in TM Format Group 1 and the input battery voltage in TM Format Group 2.

Example: VFd Tracking Pod message frame header and data.
PF 1 1001 1100 0000 0101 (9C05)
GRDCS/GMCS VFd, Tracking Pod frame, 5 data words, TM Format Group 1.
PF 2 0000 0010 1000 0000 (0280)
Pod address is 5, TM Format Group 1, no POR's or errors.

PF 3 JJJJ JJJJ JJJJ KKKK
Radar altimeter reading (J).
PF 4 KKKK KKKK LLLL LLLL
Barometric pressure reading (K).
PF 5 LLLL MMMM MMMM MMMM
Hardware temperature sensors (L & M).

Global Positioning System (GPS) HDIS Pod Message Frame (9Bxx)

The VFd message frame for the MTACS GPS Pod contains the message "type" field, the frame length, the 9 bit address of the pod, and GPS data. The GPS Pod message frame is carried in any tracking message.

VFd Message - GPS Pod Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
Gp	1	ffff	oooo	llll	llll
Gp	2	aaaa	aaaa	ahhh	hrde
Gp	n	gggg	gggg	gggg	gggg

VFd Message - GPS Pod Message Frame - Content

Frame Field	Description
ffff	The message frame "type" field (1001 binary).
oooo	The message frame "mode" field (1011 binary).
llllllll	The length of this GPS Pod message frame, in sixteen bit words.
aaaaaaaaa	The nine bit address of this participant.
hhhh	An echo of the message number of the VFu message.
r	GPS Pod reset. Equals 1 if a POR or wake-up timer event.
d	GPS data error. The GPS data is invalid if *d* is equal to 1.
e	VFd message error. The message is invalid if *e* is equal to 1.

gggg gggg gggg gggg	Downlink data from the GPS Subsystem. This includes a message header word, data words, and a message checksum word.

Flight Termination Transponder (FTT) Message Frame (99xx)

The VFd message may contain one FTT message frame which consists of a frame header and *n* number of words of FTT data. FTT's are *only* installed in participants which require either tracking (i.e., Shooters) or tracking and/or safety destruct capabilities (i.e., Missiles).

> **Note:** Two words are needed for *each* transponder used. The first word (A) has a 9 bit address with a 6 bit delay. The second word (B) repeats the address and contains the control bits required for one FTT equipped player.

VFd Message - GPS Pod Message Frame - Layout

Word	**#**	**msb-**	**- - - -**	**- - - -**	**-lsb**
FH	1	ffff	oooo	llll	llll
FD	n	aaaa	aaaa	aebb	bltt

VFd Message - GPS Pod Message Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (1001 binary).
oooo	The message frame "mode" field (1001 binary).
llllllll	The length of the FTT message frame in 16 bit words.
aaaaaaaaa	The nine bit binary FTT address. Each FTT has its own unique address which is the binary equivalent of the decimal serial number of the FTT. **Note:** Unless these address bits are identical to the serial number of the FTT, the FTT will neither respond with a downlink message nor react to the control information contained in an uplink message.
e	Message error.

	This bit is "on" (equal to 1) if: • The message error bit was set in the VFu, • A parity error occurred, or • A "missing data" pulse (erasure) was detected.
bbb	These bits give an indication of the FTT input power voltage level. They give a binary indication relative to the low voltage reference level (LV) with the least significant bit (LSB) representing 0.5 volts. <u>Valid Low Voltage Reference Levels</u>: 000 - Less than LV. 001 - 0 to 0.5 volts above LV. 010 - 0.5 to 1.0 volts above LV. 011 - 1.0 to 1.5 volts above LV. 100 - 1.5 to 2.0 volts above LV. 101 - 2.0 to 2.5 volts above LV. 110 - 2.5 to 3.0 volts above LV. 111 - More than 3.0 volts above LV. **<u>Note</u>:** The accuracy of this indication is ±1/2 LSB or ±0.25 volts.
l	This bit indicates the state of the "Safe Separation" input to the FTT. This bit equals 1 if the Safe Separation input voltage is above +20 volts indicating *"No Safe Separation"*. This bit equals 0 if the Safe Separation input voltage is below +5 volts or an open circuit indicating *"Safe Separation"*.
tt	These bits indicate the status of the output destruct discretes. The discrete outputs are monitored internally by the FTT to provide an indication of their status. The most significant discrete output is encoded into 2 bits and placed into this position in the VFd message. <u>Possible Active Discretes (in ascending significance)</u>: 00 - None. 01 - Prearm. 10 - Arm. 11 - Fire.

	Note: An "Arm" indication does *not* necessarily mean that "Prearm" is active. A "Fire" indication does *not* necessarily mean that both "Prearm" and "Arm" are active.

Example: VFd FTT message frame header and data.

```
FH 1 1001 1001 0000 0101  (9905)
    Length is 5 words (4 FTT's).  Track mode.
FD 1 0000 0010 1010 1000
    FTT address is 5, 2.0 to 2.5 volts above LV, "No Safe
Separation", "Safe" status.
FD 2 0000 0001 1001 0101
    FTT address is 3, 0.5 to 1.0 volts above LV, "Safe
Separation", "Safe" status.
FD 3 0000 0010 0011 1000
         FTT address is 4, more than 3.0 volts above LV,
"No Safe Separation", "Safe" status.
FD 4 0000 0000 1001 0110
         FTT address is 1, 0.5 to 1.0 volts above LV,
"Safe Separation", "Arm" status.
```

Slave Message Frame (9Axx)

The V Fd message frame for the Slave stations contain the message "type" field, the message "mode" field, the frame length, the 9 bit address of the Slave station, and optional TOA data.

VFd Message - Slave Message Frame - Layout

Word	#	msb-	- - - -	- - - -	-lsb
Sn	1	ffff	oooo	llll	llll
Sn	2	aaaa	aaaa	asss	ssss
Sn	3	aaaa	aaaa	avtt	tttt
Sn	4	tttt	tttt	tttt	tttt
Sn	n	dddd	dddd	dddd	dddd

VFd Message - Slave Message Frame - Content

Frame Field	**Description**
ffff	The message frame "type" field (1001 binary).
oooo	The message frame "mode" field (1010 binary).
llllllll	The length of the Slave message frame in 16 bit words.
aaaaaaaaa	The nine bit address of this datalink station.
sssssss	The Slave's status bits 0 thru 6, as follows: 0 = POR (a power-on-reset has occurred since the last downlink). 1 = **<SPARE>** 2 = **<SPARE>** 3 = **<SPARE>** 4 = **<SPARE>** 5 = **<SPARE>** 6 = **<SPARE>**
aaaaaaaaa	The address associated with adjacent TOA fields.
v	The validity bit for the current TOA reading. If this bit is 1, this word and the next word will be invalid.
tttttt	Most significant 6 TOA bits associated with the adjacent address field.
tttttttttttttttt	Least significant 16 TOA bits associated with the preceding address field.
dddd dddd dddd dddd	Words Sn 3 and Sn 4 repeated for each system participant for which a TOA measurement is available.

Error Handling

As the VFd message is transmitted from station to station, transmission/reception errors are inevitable. The station receiving the message in error will take action according to the position of the error.

Message Length Word Error

- If an error occurs in the *first* word of the VFd message, the message will be rejected by the intended receiving station and thus the message sequence will fail to progress the message through the downlink stations.

Drone Message Frame Errors

- If an error occurs in the *first* word of the VFd Drone message frame, the rest of the downlink message is deleted and the message length field is adjusted accordingly.
- If an error occurs in the *second* word of the VFd Drone message frame, the Drone's address word will be set to zeros by that station (Master or Relay). The subsequent data words will *not* be valid.
- If an error occurs in the *third* through the *last* word of the VFd Drone message frame, bit two of the *second* word will be set to one to indicate that the rest of the Drone's telemetry data is invalid. The station detecting the error (Master or Relay) will also set their error bit equal to one.

FTT Message Frame Errors

- If an error occurs in the *first* word of the VFd FTT message frame, the rest of the downlink message will be deleted and the message length field will be adjusted accordingly.
- If an error occurs in the *second* through the *last* word of the VFd FTT message frame, the associated data word will be set equal to zeroes.

Slave Message Frame Errors

- If an error occurs in the *first* word of the VFd Slave message frame, the rest of the downlink message will be deleted and the message length field will be adjusted accordingly.
- If an error occurs in the *second* word of the VFd Slave message frame, the word will be set to zeroes.

- If an error occurs in the *third* through the *last* word of the VFd Slave message frame, the associated validity bit (v) will be set and the associated TOA reading will be lost.

Time-of-Arrival (TOA) Data

The final datalink function (after transmitting uplink commands and receiving downlink status), is to collect TOA readings for all pertinent stations. The TOA reading is a measurement of the *difference* between the Master's uplink transmission and the responding station's downlink transmission. If the station taking the TOA reading does *not* hear the responding station's downlink transmission, then the two words associated with that TOA reading will *not* be present in the downlink transmission. The TOA data field is 22 bits in length. The resolution of the Least Significant Bit is 1/120 MHz.

A Relay station (including the ISc) can perform as a clocking station and take TOA measurements only if the t bit is "on" for that relay station in the uplink message (reference the VFu Message Header Frame). If the Relay station fails to hear the Master VFu message, then all of the associated TOA data for this datalink message sequence will *not* be present in the VFd message. The TOA readings taken by a Relay station will be a delta of the Master's uplink and the addressed stations downlink. A Relay station will have TOA data for each Drone (when present), each Tracking Pod (when present), each GPS Pod (when present), each FTT (when present), and each Beacon (when present).

The TOA readings taken by a Master will be a delta of the Master's uplink and the addressed stations downlink. The Master station will have TOA data for each Drone (when present), each Tracking Pod (when present), each GPS Pod (when present), each FTT (when present), and each Beacon (when present).

The TOA readings taken by Slave 1 and Slave 2 will be a delta of the Master's uplink and the addressed station's downlink. Both Slave stations will have TOA data for each Drone (when present), each Tracking Pod (when present), each GPS Pod (when present), and each FTT (when present). The tables below provide the TOA to Raw Range conversion formulas used by GRDCS/ GMCS, participant delay values, and "nominal" calibration values.

TOA Conversion/Computation

To start the process, each of the expected TOA's is qualified for availability. These TOA's *must* be converted into ranges from the known locations. To accomplish this each TOA is decomposed into their individual segments of time. The following formulas (listed in Steps 1-4 in the tables below) are used in the conversion and computation process.

TABLE 3	**Time-of-Arrival (TOA) to Raw Range Conversion Formula**
Range	**Conversion Formula**
Master to Object(*x*) **(1)**	**TOA (*m* - *x*) = [*m*TOA (*x*) /K (*m*) - DLY (*x*) - CAL (*x*) - CAL (*m*) - *m*DIFF (*m*) - 2* (BIAS (*x*) + BIAS (*m*))] /2**
Non-Master to Object(*x*) **(2)**	**TOA (*s* - *x*) = *s*TOA (*x*) /K (*s*) - TOA (*m* - *x*) - DLY (*x*) - CAL (*x*) - 2* (BIAS (*x*) + RNGCC (*s* - *m*)**

TABLE 4	**Raw Range Computation Formula**
Range Computation	**Computation Formula**
(3)	**RNGRAW (*m* - *x*) = TOA (*m* - *x*) * CS**
(4)	**RNGRAW (*s* - *x*) = TOA (*s* - *x*) * CS**

TABLE 5 Time-of-Arrival Term Definitions

Term	Definition
m	Master index.
s	Non-Master index (i.e., Slave, Relay, ISc, etc.).
x	Object index.
TOA (*m* - *x*)	Master to Object range (60 MHz clock counts).
TOA (*s* - *x*)	Non-Master to Object range (60 MHz clock counts).
RNGCC (*s* - *m*)	Range between Master and Non-Master (60 MHz clock counts).
***m*TOA (*x*)**	Master TOA to Object.
***s*TOA (*x*)**	Non-Master TOA to Object.
CAL (*m*)	Master calibration delay (60 MHz clock counts).
***m*DIFF (*m*)**	Master difference delay (60 MHz clock counts).
BIAS (*m*)	Master antenna and cable delay (1 way 60 MHz clock counts).
K (*m*)	Master clock constant (1 = 60 MHz; 2 = 120 MHz).
K (*s*)	Non-Master clock constant (1 = 60 MHz; 2 = 120 MHz).
CAL (*x*)	Object calibration delay (60 MHz clock counts).
DLY (*x*)	Object commanded delay (60 MHz clock counts).
BIAS (*x*)	Object antenna and cable delay (1 way 60 MHz clock counts).

TABLE 6 Range Computation Term Definitions

Term	Definition
RNGRAW (*m* - *x*)	Raw range from Master to Object (in feet).
RNGRAW (*s* - *x*)	Raw range from Non-Master to Object (in feet).
CS	Constant 16.39285 feet/60 MHz clock count.

TABLE 7 Subsystem Delay Value Equations (60 MHz Clock Counts

Subsystem	Delay Value Equation
ABS II	**DLY(ABS II)** = 32768 * N + 4102
DLS	**DLY(DLS)** = 30000 * N + 972
DLU	**DLY(DLU)** = 30000 * N + 972
SPVI	**DLY(SPVI)** = 30000 * N + 780
Tracking Pod	**DLY(TRK POD)** = 30240 *N - 1380
TTU	**DLY(TTU)** = 30240 * N - 1380
FTT	**DLY(FTT)** = 15882 * (264.7 microseconds)
TRC	**DLY(TRC)** = 30000 * N + 972
DLP	**DLY(DLP)** = 30240 * N - 7850
WRTTM	**DLY(WRTTM)** = 15000 * N - 70

Note: The *N* value specifies the "delay count" for the subsystem device.

TABLE 8 "Nominal" Calibration Values per Subsystem

Subsystem	Calibration Value	CALBOX Type
ABS II	929	(1)
DLS	135	(2)
DLU	130	(6)
SPVI	138	(7)
Tracking Pod	135	(3)
TTU	127	(7) (MTACS Only!)
FTT	155	(4)
DPOD	135	(5)
TRC	130	(8) (MTACS Only!)
DLP	127	(9) (MTACS Only!)
MPOD	135	(8)
SPV4	135	(9)

TABLE 9 Conversion Factor for Cable Delays (Nanoseconds to Clock Counts)

<u>Conversion Factor</u>

Clock Counts = (60 * 10 6) * (Seconds * 10** -9)**

Clock Counts = (60 MHz) * (Nanoseconds * 10 -3)**

The system delays (in 1/2 ms counts), for a maximally configured mission consisting of 22 participants (17 of which are airborne), are listed in the table below. Using these delays, any three drone vehicles can be placed into either the D1 or D2 tracking message by simply changing the Drone's delay value.

TABLE 10 D1/D2 Tracking Message - Maximum System Configuration Delays

Tracking Message	Participant	Delay
D1	ISc	63
	ISr	40
	ISm	29
	IS1	21
	IS2	18
	DRN1	5
	DRN2	9
	DRN3	13
D2	ISc	63
	ISr	40
	ISm	29
	S2	21
	S1	18
	DRN4	5

Note: All drone aircraft vehicles are tracked and controlled at a rate of 10 times per second.

TABLE 11 HF Tracking Message - Maximum System Configuration Delays

Tracking Message	Participant	Delay
HF	ISc	63
	ISm	48
	IS1	40
	IS2	37
	BCN1	12
	BCN2	14

BCN3	16
BCN4	18
SHT1	22
SHT2	24
SHT3	22
SHT4	24
OTH1	27
MSL1	4
MSL2	6
MSL3	8
MSL4	10

Note: The following rates apply:

- Missiles (MSL) will be updated at a rate of 10 times/sec (100 ms interval).
- Tracking Pods (SHT) will be updated at a rate of 5 times/sec (200 ms interval).
- Other A/C (OTH) or Airborne Platforms which are used as clocking stations will be updated at a rate of 2.5 times/sec (400 ms interval).

Ground Computer Data Words

After the VFd message is received by the ISc and passed on to the ground computer, five data words are added to the beginning of the message. These words precede the normal message length word and are *not* included in the message length count. The first three words (C, D, & E) contain the time stamp data for when the downlink message was received.

The fourth word (PPPP) contains the number of words that were transferred from the ISc to the ground computer. This is the actual DMA transfer count. When the system is functioning properly, this word count should match a "normal" message length word. Whenever a transfer error occurs, the two word counts will be different. The software will flag the VFd as invalid whenever the two word counts do *not* match.

VFd Message - Ground Computer Data Words - Content

Frame Field	Description
Cmmm	Milliseconds.
Dmss	Minutes and seconds.
Ehhm	Hours and minutes.
PPPP	Ground computer status word.
SSSS	Software status word.
LLLL	Message length.
CCCC	ISc code.
UUUU	Wrap of the first 120 words of the VFu message.

The fifth word (SSSS) contains the software status word and error detection code. This word is divided into halves. The "low-order" 8 bits are used by the ground computer to indicate errors detected while transferring the VFd message. The "high-order" 8 bits are used by the system to store the error code that caused the VFd to be flagged as invalid.

VFd Message - Ground Computer Data (Low-Order SW Status)

Low-Order Bits	Description
0	No data received from the ISc interface.
1	Output buffer word count error.
2	Microwave parity error on input from ISc.
3	Serial interface error; data overrun.
4	**<SPARE>**
5	**<SPARE>**
6	**<SPARE>**
7	ISc path number.

VFd Message - Ground Computer Data (High-Order SW Status)

High-Order Bits	Description
01 (01X)	Message length is greater than 512.
02 (02x)	Not a GRDCS/GMCS message frame.
03 (03x)	Unknown message frame "type".
04 (04x)	Sum of all message frames exceeds the message length.
05 (05x)	Too many message frames found in the downlink message.
06 (06x)	Invalid drone vehicle "type" encountered.
07 (07x)	Bad status from DR-11 interface.
08 (08x)	Message length mismatch.
12 (0Cx)	Invalid TOA address.
13 (0Dx)	Message frame pointer is greater than the message frame length.
14 (0Ex)	Invalid source address.
20 (14x)	Multiple message frames from the same drone vehicle.
21 (15x)	Invalid drone vehicle address.
23 (17x)	Drone data word length error.
30 (1Ex)	Invalid FTT address.
31 (1Fx)	FTT message frame header only.
40 (28x)	Multiple message frames from same Tracking Pod participant.
41 (29x)	Invalid Tracking Pod address.
43 (2Bx)	Message length error.

If the LLLL word is set to zero, this indicates a "time-out" message. A "time-out message" is a downlink message with a word length of zero (0) words in word six and a code value in word seven. The CCCC word is used to indicate the "type" of time-out encountered. The CCCC word is the first ten words of the VFu message that was associated with this VFd message. The CCCC word has four defined code values. The first three are related to the ground computer. The forth is generated by the software.

VFd Message - Ground Computer Data (Time-Out Codes)

Code Number	Description
1	Input time-out from the ground computer to the ISc.
2	Output time-out from the ISc to the ground computer.
3	Invalid uplink word count detected by the ground computer.
4	Software ACTIVATE in progress; discard this downlink message.

In the last field (UUUU), the VFu message is wrapped back into the VFd message so that its validity can be checked in "real-time".

Chapter 4
Appendices

The following tables list the discrete and proportional commands for the various drone vehicle types in both the uplink and downlink messages.

Appendix A - VFu QF-4 Drone Frame (Uplink)

VFu QF-4 Drone Frame Discrete Commands				
Word	**Bit**	**DIC**	**Name**	**Comments**
4	15	01	PSO	Pitch Stick Out of Detent
	14	02	LSO	Lateral Stick Out of Detent
	13	03	Altitude Hold (M)	Barometric AH
	12	04	Wings Level (M)	
	11	05	Barrel Roll G Type	
	10	06	Barrel Roll (M)	
	09	07	G Mode Maneuver (M)	
	08	08	Hold to Arm	
	07	09	Destruct Arm	
	06	10	Destruct	
	05	11	SHOT	
	04	12	Master Off, Right	
	03	13	Master Off, Left	
	02	14	Safe/Arm Device Arm	
	01	15	Safe/Arm Device Safe	
	00	16	Scoring Calibration	
5	15	17	Heading Hold Inhibit	

	14	18	SHOP	Speed Hold on Pitch
	13	19	Smoke On	
	12	20	Backup AFCS On	
	11	21	Speedbrake Out	
	10	22	Takeoff Abort	
	09	23	Anti-Skid Off	
	08	24	RAH	Radar Altitude Hold
	07	25	Payload 7	
	06	26	Payload 8	
	05	27	Payload 9	
	04	28	Payload 10	
	03	29	Payload 11	
	02	30	Payload 12	
	01	31	Pylon Drop	
	00	32	Auto Test	Always cleared
6	15	33	Auto Mode	
	14	34	Air Start Ignition	
	13	35	EM Servos Only	Electro Mechanical
	12	36	EH Servos Only	Electro Hydraulic
	11	37	Scoring On	
	10	38	Failsafe On	
	09	39	Nose Wheel Steering	
	08	40	TSB - Left	Throttle Stop Bypass
	07	41	TSB - Right	Throttle Stop Bypass

	06	42	Auto Takeoff	ATO
	05	43	Brakes On	
	04	44	CTS 1	
	03	45	Landing Takeoff	
	02	46	MHOT	
	01	47	MHOP	
	00	48	TOA Reset	
7	15	49	Chute Deploy	
	14	50	Hook Extend	
	13	51	AAR	
	12	52	Gear Down	
	11	53	Emergency Gear Extend	
	10	54	Spare	
	09	55	Payload 1	
	08	56	Payload 2	
	07	57	Payload 3	
	06	58	Payload 4	
	05	59	Payload 5	
	04	60	Payload 6	
	03	61	Spare	
	02	62	Nose Down Enabled	
	01	63	Slats Out/Flaps Down	
	00	64	Emergency Flaps Extend	

8	15	65	Slats Override	
	14	66	No Air Data Command	
	13	67	Generator Off, Left	
	12	68	Generator Off, Right	
	11	69	External Center Tank Transfer	
	10	70	Internal Wing Fuel Dump	
	09	71	Internal Wing Transfer Stop	
	08	72	Fuel Tank Depressurization	
	07	73	External Wing Tank Transfer	
	06	74	No Air Data Multiplex	
	05	75	Message Update	
	04	76	Spare	
	03	77	Spare	
	02	78	Spare	
	01	79	Spare	
	00	80	Spare	

VFu QF-4 Drone Frame Proportional Commands				
Word	**Bit**	**PRC**	**Name**	**Comments**
9	15	01	Throttle Position Left	Most Significant Bit
	14	01	Throttle Position	
	13	01	Throttle Position	

	12	01	Throttle Position	
	11	01	Throttle Position	
	10	01	Throttle Position	
	09	01	Throttle Position	
	08	01	Throttle Position	
	07	01	Throttle Position	
	06	01	Throttle Position	Least Significant Bit
	05	02	Throttle Position Right	Most Significant Bit
	04	02	Throttle Position	
	03	02	Throttle Position	
	02	02	Throttle Position	
	01	02	Throttle Position	
	00	02	Throttle Position	
10	15	02	Throttle Position	
	14	02	Throttle Position	
	13	02	Throttle Position	
	12	02	Throttle Position	Least Significant Bit
	11	03	Roll	Most Significant Bit
	10	03	Roll	
	09	03	Roll	
	08	03	Roll	
	07	03	Roll	
	06	03	Roll	
	05	03	Roll	

	04	03	Roll	
	03	03	Roll	
	02	03	Roll	
	01	03	Roll	
	00	03	Roll	Least Significant Bit
11	15	04	Pitch	Most Significant Bit
	14	04	Pitch	
	13	04	Pitch	
	12	04	Pitch	
	11	04	Pitch	
	10	04	Pitch	
	09	04	Pitch	
	08	04	Pitch	
	07	04	Pitch	
	06	04	Pitch	
	05	04	Pitch	
	04	04	Pitch	Least Significant Bit
	03	05	Airspeed Reference Rate	Most Significant bit
	02	05	Airspeed Reference Rate	
	01	05	Airspeed Reference Rate	
	00	05	Airspeed Reference Rate	
12	15	05	Airspeed Reference Rate	
	14	05	Airspeed Reference Rate	

	13	05	Airspeed Reference Rate	
	12	05	Airspeed Reference Rate	
	11	05	Airspeed Reference Rate	
	10	05	Airspeed Reference Rate	
	09	06	Rudder or Heading	Most Significant Bit
	08	06	Rudder or Heading	Least Significant Bit
	07	06	Rudder or Heading	
	06	06	Rudder or Heading	
	05	06	Rudder or Heading	
	04	06	Rudder or Heading	
	03	06	Rudder or Heading	
	02	06	Rudder or Heading	
	01	06	Rudder or Heading	
	00	06	Rudder or Heading	Least Significant Bit
13	15	07	Emergency Roll	Most Significant Bit
	14	07	Emergency Roll	
	13	07	Emergency Roll	
	12	07	Emergency Roll	
	11	07	Emergency Roll	
	10	07	Emergency Roll	
	09		Emergency Roll	
	08	07	Emergency Roll	Least Significant Bit
	07	08	Escape Delay Time	Most Significant Bit
	06	08	Escape Delay Time	

	05	08	Escape Delay Time	
	04	08	Escape Delay Time	
	03	08	Escape Delay Time	
	02	08	Escape Delay Time	
	01	08	Escape Delay Time	
	00	08	Escape Delay Time	Least Significant Bit
14	15	09	Payload 1 / Ps	Most Significant Bit Ps when DIC 66 & 74 True
	14	09	Payload 1 / Ps	
	13	09	Payload 1 / Ps	
	12	09	Payload 1 / Ps	
	11	09	Payload 1 / Ps	
	10	09	Payload 1 / Ps	
	09	09	Payload 1 / Ps	
	08	09	Payload 1 / Ps	Least Significant Bit
	07	10	Payload 2 / Ps	Most Significant Bit
	06	10	Payload 2 / Ps	
	05	10	Payload 2 / Ps	
	04	10	Payload 2 / Ps	
	03	10	Payload 2 / Ps	
	02	10	Payload 2 / Ps	
	01	10	Payload 2 / Ps	
	00	10	Payload 2 / Ps	Least Significant Bit
15	15	11	Payload 3 / Qc	Most Significant Bit Qc

				when DIC 66 & 74 True
	14	11	Payload 3 / Qc	
	13	11	Payload 3 / Qc	
	12	11	Payload 3 / Qc	
	11	11	Payload 3 / Qc	
	10	11	Payload 3 / Qc	
	09	11	Payload 3 / Qc	
	08	11	Payload 3 / Qc	Least Significant Bit
	07	12	Payload 4 / Qc	Most Significant Bit
	06	12	Payload 4 / Qc	
	05	12	Payload 4 / Qc	
	04	12	Payload 4 / Qc	
	03	12	Payload 4 / Qc	
	02	12	Payload 4 / Qc	
	01	12	Payload 4 / Qc	
	00	12	Payload 4 / Qc	Least Significant Bit

Appendix B - VFd QF-4 Drone Frame (Downlink)

VFd QF-4 Drone Frame Discrete Telemetry

Word	**Bit**	**DIT**	**Name**	**Comments**
3	15	01	Anti-Skid Inoperative	
	14	02	Fuel Low	
	13	03	Spare	
	12	04	Altitude Hold	Baro
	11	05	Autopilot Engaged	
	10	06	Speed Hold on Pitch	SHOP
	09	07	Speed Hold on Throttle	SHOT
	08	08	CADC Failure	
	07	09	Left Ext. Wing No Fuel Flow	
	06	10	Radar Altitude Hold	RAH
	05	11	Oil Pressure Low - #1	
	04	12	Oil Pressure Low - #2	
	03	13	PC1 Hydraulic System Fail #1	
	02	14	Center Ext. No Fuel Flow	
	01	15	Rt. Ext. Wing No Fuel Flow	
	00	16	Pneumatic Pressure Low	
4	15	17	Mach Hold on Pitch	MHOP
	14	18	Mach Hold on Throttle	MHOT

	13	19	G Mode Maneuver	
	12	20	Landing Takeoff	LTO
	11	21	Nosewheel Steering Engaged	NWS
	10	22	Generator Out - Left	
	09	23	Generator Out - Right	
	08	24	Auxiliary Air Door Fail	
	07	25	Autopilot Control Override	
	06	26	Weight on Gear	
	05	27	Gears Down and Locked	
	04	28	Auto Takeoff	ATO
	03	29	CTS 1 Active	
	02	30	Backup AFCS Failed	
	01	31	Backup AFCS Engaged	
	00	32	Escape in Progress	
5	15	33	Escape Complete	
	14	34	Gears Unsafe	
	13	35	Engine Fire Warning - Left	
	12	36	Engine Fire Warning - Right	
	11	37	Transformer Rectifier Fail - Left	
	10	38	UHF Check Channel	
	09	39	Fail Safe Arm	
	08	40	Destruct Arm	

	07	41	Destruct Explode	
	06	42	Takeoff Abort	TOA
	05	43	PC2 Hydraulic System Failed	
	04	44	Barrel Roll Maneuver	
	03	45	Payload 7	
	02	46	Payload 8	
	01	47	Payload 9	
	00	48	Payload 10	
6	15	49	Payload 11	
	14	50	Payload 12	
	13	51	All Attitude Recovery	AAR
	12	52	Transformer Rectifier Fail - Right	
	11	53	Bus Tie Open	
	10	54	Primary AFCS Failed	
	09	55	Utility Hydraulic System Fail	
	08	56	Hold to Arm	
	07	57	Safe and Arm Device Safe	
	06	58	Safe and Arm Device Armed	
	05	59	Wings Level	
	04	60	Payload 5	
	03	61	Payload 6	
	02	62	Payload 1	

	01	63	Payload 2	
	00	64	Payload 3	
7	15	65	Payload 5	
	14	66	Non Std Gains or Telemetry	
	13	67	Flaps Down	
	12	68	Engine Overheat - Left	
	11	69	Engine Overheat - Right	
	10	70	Radar Altimeter Failed	
	09	71	EM Servos Only	
	08	72	EH Servos Only	
	07	73	Pitch Mode Transition	
	06	74	Roll Mode Transition	
	05	75	Yaw Mode Transition	
	04	76	Fire Warn System Fail	
	03	77	Timed Turn in Progress	
	02	78	Slats Out	
	01	79	Tail Hook Down	
	00	80	Spare	

VFd QF-4 Drone Frame Proportional Telemetry				
Word	**Bit**	**PRT**	**Name**	**Comments**
8	15	1	Baro Altitude	
	14	1		
	13	1		

	12	1		
	11	1		
	10	1		
	09	1		
	08	1		
	07	1		
	06	1		
	05	1		
	04	1		
	03	1		
	02	1		
	01	1		Least Significant Bit
	00	2	Altitude Reference	Most Significant Bit
9	15	2		
	14	2		
	13	2		
	12	2		
	11	2		
	10	2		
	09	2		
	08	2		
	07	2		
	06	2		
	05	2		

	04	2		
	03	2		
	02	2		Least Significant Bit
	01	3	Radar Altitude	Most Significant Bit
	00	3		
10	15	3		
	14	3		
	13	3		
	12	3		
	11	3		
	10	3		
	09	3		
	08	3		
	07	3		
	06	3		
	05	3		
	04	3		
	03	3		
	02	3		
	01	3		Least Significant Bit
	00	4	Baro Altitude Rate	Most Significant Bit
11	15	4		
	14	4		

	13	4		
	12	4		
	11	4		
	10	4		
	09	4		
	08	4		
	07	4		Least Significant Bit
	06	5	Indicated Airspeed	Most Significant Bit
	05	5		
	04	5		
	03	5		
	02	5		
	01	5		
	00	5		
12	15	5		
	14	5		
	13	5		
	12	5		Least Significant Bit
	11	6	Airspeed Reference	Most Significant Bit
	10	6		
	09	6		
	08	6		
	07	6		
	06	6		

	05	6		
	04	6		
	03	6		
	02	6		
	01	6		Least Significant Bit
	00	7	Mach	Most Significant Bit
13	15	7		
	14	7		
	13	7		
	12	7		
	11	7		
	10	7		
	09	7		
	08	7		
	07	7		
	06	7		
	05	7		Least Significant Bit
	04	8	Roll	Most Significant Bit
	03	8		
	02	8		
	01	8		
	00	8		
14	15			

	14	8		
	13	8		
	12	8		
	11	8		
	10	8		
	09	8		Least Significant Bit
	08	9	Heading	Most Significant Bit
	07	9		
	06	9		
	05	9		
	04	9		
	03	9		
	02	9		
	01	9		
	00	9		
15	15	9		
	14	9		
	13	9		Least Significant Bit
	12	10	Pitch	Most Significant Bit
	11	10		
	10	10		
	09	10		
	08	10		
	07	10		

	06	10		
	05	10		
	04	10		
	03	10		
	02	10		Least Significant Bit
	01	11	Roll Rate	Most Significant Bit
	00	11		
16	15	11		
	14	11		
	13	11		
	12	11		
	11	11		
	10	11		
	09	11		
	08	11		Least Significant Bit
	07	12	Primary Yaw Rate	Most Significant Bit
	06	12		
	05	12		
	04	12		
	03	12		
	02	12		
	01	12		
	00	12		

17	15	12		Least Significant Bit
	14	13	Pitch Rate	Most Significant Bit
	13	13		
	12	13		
	11	13		
	10	13		
	09	13		
	08	13		
	07	13		
	06	13		Least Significant Bit
	05	14	Backup Yaw Rate	Most Significant Bit
	04	14		
	03	14		
	02	14		
	01	14		
	00	14		
18	15	14		
	14	14		
	13	14		Least Significant Bit
	12	15	Aileron Deflection - Right	Most Significant Bit
	11	15		
	10	15		
	09	15		

	08	15		
	07	15		
	06	15		
	05	15		Least Significant Bit
	04	16	Aileron Deflection - Left	Most Significant Bit
	03	16		
	02	16		
	01	16		
	00	16		
19	15	16		
	14	16		
	13	16		Least Significant Bit
	12	17	Stabilator Deflection	Most Significant Bit
	11	17		
	10	17		
	09	17		
	08	17		
	07	17		
	06	17		
	05	17		Least Significant Bit
	04	18	Rudder Deflection	Most Significant Bit
	03	18		
	02	18		
	01	18		

	00	18		
20	15	18		
	14	18		
	13	18		Least Significant Bit
	12	19	Pitch Trim Integral	Most Significant Bit
	11	19		
	10	19		
	09	19		
	08	19		
	07	19		
	06	19		
	05	19		Least Significant Bit
	04	20	Pitch Attitude Reference	Most Significant Bit
	03	20		
	02	20		
	01	20		
	00	20		
21	15	20		
	14	20		
	13	20		Least Significant Bit
	12	21	Longitudinal G's	Most Significant Bit
	11	21		
	10	21		

	09	21		
	08	21		
	07	21		
	06	21		
	05	21		Least Significant Bit
	04	22	Normal G's	Most Significant Bit
	03	22		
	02	22		
	01	22		
	00	22		
22	15	22		
	14	22		
	13	22		Least Significant Bit
	12	23	Lateral G's	Most Significant Bit
	11	23		
	10	23		
	09	23		
	08	23		
	07	23		
	06	23		
	05	23		
	04	23		
	03	23		
	02	23		Least Significant Bit

	01	24	Angle of Attack	Most Significant Bit
	00	24		
23	15	24		
	14	24		
	13	24		
	12	24		
	11	24		
	10	24		
	09	24		
	08	24		Least Significant Bit
	07	25	AFCS Failure Code	Most Significant Bit
	06	25		
	05	25		
	04	25		
	03	25		
	02	25		
	01	25		
	00	25		Least Significant Bit
24	15	26	Roll Trim Integral	Most Significant Bit
	14	26		
	13	26		
	12	26		
	11	26		

	10	26		
	09	26		
	08	26		
	07	27/36	Destruct Battery Voltage UHF Signal Strength	Multiplex Group 1 Multiplex Group 2
	06	27/36		
	05	27/36		
	04	27/36		
	03	27/36		
	02	27/36		
	01	27/36		
	00	27/36		Least Significant Bit
25	15	28/37	Tape Fuel Quantity Counter Fuel Quantity	Multiplex Group 1 Multiplex Group 2
	14	28/37		
	13	28/37		
	12	28/37		
	11	28/37		
	10	28/37		
	09	28/37		
	08	28/37		Least Significant Bit
	07	29/38	Throttle Position - Left Throttle Position - Right	Multiplex Group 1 Multiplex Group 2
	06	29/38		
	05	29/38		
	04	29/38		

	03	29/38		
	02	29/38		
	01	29/38		
	00	29/38		Least Significant Bit
26	15	30/39	Engine RPM's - Left Engine RPM's - Right	Multiplex Group 1 Multiplex Group 2
	14	30/39		
	13	30/39		
	12	30/39		
	11	30/39		
	10	30/39		
	09	30/39		
	08	30/39		
	07	31/40	EGT - Left EGT - Right	Multiplex Group 1 Multiplex Group 2
	06	31/40		
	05	31/40		
	04	31/40		
	03	31/40		
	02	31/40		
	01	31/40		
	00	31/40		
27	15	32/41	Nozzle Position - Left Nozzle Position - Right	Multiplex Group 1 Multiplex Group 2
	14	32/41		

	13	32/41		
	12	32/41		
	11	32/41		
	10	32/41		
	09	32/41		
	08	32/41		Least Significant Bit
	07	33/42	Payload 1 Payload 2	Multiplex Group 1 Multiplex Group 2
	06	33/42		
	05	33/42		
	04	33/42		
	03	33/42		
	02	33/42		
	01	33/42		
	00	33/42		Least Significant Bit
28	15	34/43	Payload 3 Payload 4	Multiplex Group 1 Multiplex Group 2
	14	34/43		
	13	34/43		
	12	34/43		
	11	34/43		
	10	34/43		
	09	34/43		
	08	34/43		Least Significant Bit
	07	35/44	QC - Dynamic Pressure YTCO	Multiplex Group 1 Multiplex Group 2

	06	35/44		
	05	35/44		
	04	35/44		
	03	35/44		
	02	35/44		
	01	35/44		
	00	35/44		Least Significant Bit

Appendix C - VFu MQM-107D Drone Frame (Uplink)

Discrete commands.

VFu MQM-107D Drone Frame Discrete Commands				
Word	**Bit**	**DIC**	**Name**	**Comments**
4	15	01		
	14	02		
	13	03		
	12	04	Radar Altitude Hold	RAH
	11	05		
	10	06		
	09	07		
	08	08		
	07	09		
	06	10		
	05	11		
	04	12		
	03	13		
	02	14		
	01	15		
	00	16		
5	15	17	Datalink Valid	
	14	18		
	13	19	Digidops Scoring Cal	

	12	20	Banner Release	
	11	21	RH AZC-4 IR Pod	
	10	22	LH AZC-4 IR Pod	
	09	23	L-Band Transponder	
	08	24		Radar Altitude Hold
	07	25	Recovery in Progress	
	06	26	RAH Escape	Radar Altitude Hold
	05	27		
	04	28		
	03	29		
	02	30		
	01	31	Radar Altimeter Test	
	00	32	Auto Test	Always cleared
6	15	33	Escape Start	
	14	34		
	13	35		
	12	36		
	11	37	Roll Erection	
	10	38	Main Chute Deploy	Emergency
	09	39	Level Flight	
	08	40	Drogue Chute Deploy	
	07	41	High G's	
	06	42	Engine Kill	
	05	43		

	04	44		
	03	45	Recovery Arm	Emergency
	02	46	Pitch Over	
	01	47	RH TOW Deploy	DFCS
	00	48	LH TOW Deploy	DFCS
7	15	49	Digidops Scoring	
	14	50	Pitch Command Rate Limit	
	13	51	Radar Augmentation	
	12	52	Barometric Altitude Hold	
	11	53	Smoke	
	10	54	Airspeed Mode	
	09	55	Payload Arm	
	08	56		
	07	57		
	06	58		
	05	59		
	04	60		
	03	61		
	02	62		
	01	63		
	00	64		

Proportional commands.

VFu MQM-107D Drone Frame Proportional Commands				
Word	**Bit**	**PRC**	**Name**	**Comments**
8	15	01	Roll	Most Significant Bit
	14	01	Roll	
	13	01	Roll	
	12	01	Roll	
	11	01	Roll	
	10	01	Roll	
	09	01	Roll	
	08	01	Roll	
	07	01	Roll	
	06	01	Roll	Least Significant Bit
	05	02	Pitch/Acceleration	Most Significant Bit
	04	02	Pitch/Acceleration	
	03	02	Pitch/Acceleration	
	02	02	Pitch/Acceleration	
	01	02	Pitch/Acceleration	
	00	02	Pitch/Acceleration	
9	15	02	Pitch/Acceleration	

	14	02	Pitch/Acceleration	
	13	02	Pitch/Acceleration	
	12	02	Pitch/Acceleration	Least Significant Bit
	11	03	Radar Altitude	Most Significant Bit
	10	03	Radar Altitude	
	09	03	Radar Altitude	
	08	03	Radar Altitude	
	07	03	Radar Altitude	
	06	03	Radar Altitude	
	05	03	Radar Altitude	
	04	03	Radar Altitude	
	03	03	Radar Altitude	
	02	03	Radar Altitude	Least Significant Bit
	01	04	Escape Roll	Most Significant Bit
	00	04	Escape Roll	Least Significant Bit
10	15	04	Escape Roll	
	14	04	Escape Roll	
	13	04	Escape Roll	
	12	04	Escape Roll	
	11	04	Escape Roll	
	10	04	Escape Roll	
	09	04	Escape Roll	
	08	04	Escape Roll	Least Significant Bit
	07	05	Throttle	Most Significant Bit

	06	05	Throttle	
	05	05	Throttle	
	04	05	Throttle	
	03	05	Throttle	
	02	05	Throttle	
	01	05	Throttle	
	00	05	Throttle	
11	15	05	Throttle	
	14	05	Throttle	Least Significant Bit
	13	06	ECM 1	Most Significant Bit
	12	06	ECM 1	
	11	06	ECM 1	
	10	06	ECM 1	
	09	06	ECM 1	
	08	06	ECM 1	
	07	06	ECM 1	
	06	06	ECM 1	
	05	06	ECM 1	
	04	06	ECM 1	Least Significant Bit
	03	07	ECM 2	Most Significant Bit
	02	07	ECM 2	
	01	07	ECM 2	
	00	07	ECM 2	

12	15	07	ECM 2	
	14	07	ECM 2	
	13	07	ECM 2	
	12	07	ECM 2	
	11	07	ECM 2	
	10	07	ECM 2	Least Significant Bit
	09	08	Escape Roll	Most Significant Bit
	08	08	Escape Roll	
	07	08	Escape Roll	
	06	08	Escape Roll	
	05	08	Escape Roll	
	04	08	Escape Roll	
	03	08	Escape Roll	
	02	08	Escape Roll	
	01	08	Escape Roll	
	00	08	Escape Roll	Least Significant Bit

Appendix D - VFd MQM-107D Drone Frame (Drone)

VFu MQM-107D Drone Frame Proportional Commands				
Word	**Bit**	**DIT**	**Name**	**Comments**
3	15	01		
	14	02		
	13	03		
	12	04	Radar Altitude Hold	RAH
	11	05		
	10	06		
	09	07		
	08	08		
	07	09		
	06	10		
	05	11	Unreliable Radar Altitude	
	04	12	Oil Pressure Low	
	03	13		
	02	14		
	01	15		
	00	16		
4	15	17	Datalink Valid	
	14	18	Zero Time	
	13	19	Digidops Scoring Cal	
	12	20	Banner Release	DFCS

	11	21	RH AZC-4 IR Pod	GRDCS/GMCS
	10	22	LH AZC-4 IR Pod	GRDCS/GMCS
	09	23	L-Band Transponder	
	08	24		
	07	25	Recovery in Progress	
	06	26	RAH Escape	Radar Altitude Hold
	05	27		
	04	28		
	03	29		
	02	30		
	01	31	Radar Altimeter Test	
	00	32		
5	15	33	Escape Start	
	14	34	Escape Complete	
	13	35	RH AZC-4 IR Pod Received	
	12	36	LH AZC-4 IR Pod Received	
	11	37	Roll Erection	
	10	38	Main Chute Deploy	Emergency
	09	39	Level Flight	
	08	40	Drogue Chute Deploy	
	07	41	High G's	
	06	42	Engine Kill	
	05	43		

	04	44		
	03	45	Recovery Arm	Emergency
	02	46	Pitch Over	
	01	47	RH TOW Deploy	(RH ANC 2)
	00	48	LH TOW Deploy	(LH ANC 2)
6	15	49	Digidops Scoring	
	14	50	Pitch Rate Limit Active	
	13	51	Radar Augmentation	
	12	52	Barometric Altitude Hold	
	11	53	Smoke	
	10	54	Airspeed Mode	
	09	55	Payload Arm	
	08	56		
	07	57		
	06	58		
	05	59		
	04	60		
	03	61		
	02	62		
	01	63		
	00	64		

VFu MQM-107D Drone Frame Proportional Commands				
Word	**Bit**	**PRT**	**Name**	**Comments**
7	15	01	Rudder Position	Most Significant Bit
	14	01	Rudder Position	
	13	01	Rudder Position	
	12	01	Rudder Position	
	11	01	Rudder Position	
	10	01	Rudder Position	
	09	01	Rudder Position	
	08	01	Rudder Position	Least Significant Bit
	07	02	Elevator Position	Most Significant Bit
	06	02	Elevator Position	
	05	02	Elevator Position	
	04	02	Elevator Position	
	03	02	Elevator Position	
	02	02	Elevator Position	
	01	02	Elevator Position	
	00	02	Elevator Position	Least Significant Bit
8	15	03	Aileron Position	Most Significant Bit
	14	03	Aileron Position	

	13	03	Aileron Position	
	12	03	Aileron Position	
	11	03	Aileron Position	
	10	03	Aileron Position	
	09	03	Aileron Position	
	08	03	Aileron Position	Least Significant Bit
	07	04	Indicated Airspeed	Most Significant Bit
	06	04	Indicated Airspeed	
	05	04	Indicated Airspeed	
	04	04	Indicated Airspeed	
	03	04	Indicated Airspeed	
	02	04	Indicated Airspeed	
	01	04	Indicated Airspeed	
	00	04	Indicated Airspeed	
9	15	04	Indicated Airspeed	
	14	04	Indicated Airspeed	
	13	04	Indicated Airspeed	
	12	04	Indicated Airspeed	Least Significant Bit
	11	05	Barometric Altitude	Most Significant Bit
	10	05	Barometric Altitude	
	09	05	Barometric Altitude	
	08	05	Barometric Altitude	
	07	05	Barometric Altitude	
	06	05	Barometric Altitude	

	05	05	Barometric Altitude	
	04	05	Barometric Altitude	
	03	05	Barometric Altitude	
	02	05	Barometric Altitude	
	01	05	Barometric Altitude	
	00	05	Barometric Altitude	Least Significant Bit
10	15	06	Barometric/Radar Altitude Error	Most Significant Bit
	14	06	Barometric/Radar Altitude Error	
	13	06	Barometric/Radar Altitude Error	
	12	06	Barometric/Radar Altitude Error	
	11	06	Barometric/Radar Altitude Error	
	10	06	Barometric/Radar Altitude Error	
	09	06	Barometric/Radar Altitude Error	
	08	06	Barometric/Radar Altitude Error	
	07	06	Barometric/Radar Altitude Error	
	06	06	Barometric/Radar Altitude Error	
	05	06	Barometric/Radar Altitude Error	
	04	06	Barometric/Radar Altitude Error	Least Significant Bit

	03	07	Radar Altitude	Most Significant Bit
	02	07	Radar Altitude	
	01	07	Radar Altitude	
	00	07	Radar Altitude	
11	15	07	Radar Altitude	
	14	07	Radar Altitude	
	13	07	Radar Altitude	
	12	07	Radar Altitude	
	11	07	Radar Altitude	
	10	07	Radar Altitude	
	09	07	Radar Altitude	
	08	07	Radar Altitude	Least Significant Bit
	07	08	Normal Acceleration	Most Significant Bit
	06	08	Normal Acceleration	
	05	08	Normal Acceleration	
	04	08	Normal Acceleration	
	03	08	Normal Acceleration	
	02	08	Normal Acceleration	
	01	08	Normal Acceleration	
	00	08	Normal Acceleration	
12	15	08	Normal Acceleration	
	14	08	Normal Acceleration	Least Significant Bit
	13	09	Roll Angle	Most Significant Bit

	12	09	Roll Angle	
	11	09	Roll Angle	
	10	09	Roll Angle	
	09	09	Roll Angle	
	08	09	Roll Angle	
	07	09	Roll Angle	
	06	09	Roll Angle	
	05	09	Roll Angle	
	04	09	Roll Angle	Least Significant Bit
	03	10	Integrated Altitude Error	Most Significant Bit
	02	10	Integrated Altitude Error	
	01	10	Integrated Altitude Error	
	00	10	Integrated Altitude Error	
13	15	10	Integrated Altitude Error	
	14	10	Integrated Altitude Error	
	13	10	Integrated Altitude Error	
	12	10	Integrated Altitude Error	
	11	10	Integrated Altitude Error	
	10	10	Integrated Altitude Error	Least Significant Bit
	09	11	Pitch Angle	Most Significant Bit
	08	11	Pitch Angle	
	07	11	Pitch Angle	
	06	11	Pitch Angle	
	05	11	Pitch Angle	

	04	11	Pitch Angle	
	03	11	Pitch Angle	
	02	11	Pitch Angle	
	01	11	Pitch Angle	
	00	11	Pitch Angle	Least Significant Bit
14 (Group 1)	15	12	Airspeed Error	Most Significant Bit
	14	12	Airspeed Error	
	13	12	Airspeed Error	
	12	12	Airspeed Error	
	11	12	Airspeed Error	
	10	12	Airspeed Error	
	09	12	Airspeed Error	
	08	12	Airspeed Error	Least Significant Bit
	07	13	Cross Coupling	
	06	13	Cross Coupling	
	05	13	Cross Coupling	
	04	13	Cross Coupling	
	03	13	Cross Coupling	
	02	13	Cross Coupling	
	01	13	Cross Coupling	
	00	13	Cross Coupling	Least Significant Bit
15 (Group	15	14	PRC 3 Wrap - Radar Altitude Cmd.	Most Significant Bit

1)				
	14	14	PRC 3 Wrap - Radar Altitude Cmd.	
	13	14	PRC 3 Wrap - Radar Altitude Cmd.	
	12	14	PRC 3 Wrap - Radar Altitude Cmd.	
	11	14	PRC 3 Wrap - Radar Altitude Cmd.	
	10	14	PRC 3 Wrap - Radar Altitude Cmd.	
	09	14	PRC 3 Wrap - Radar Altitude Cmd.	
	08	14	PRC 3 Wrap - Radar Altitude Cmd.	Least Significant Bit
	07	15	Exhaust Gas Temperature	Most Significant Bit
	06	15	Exhaust Gas Temperature	
	05	15	Exhaust Gas Temperature	
	04	15	Exhaust Gas Temperature	
	03	15	Exhaust Gas Temperature	
	02	15	Exhaust Gas Temperature	
	01	15	Exhaust Gas Temperature	
	00	15	Exhaust Gas Temperature	Least Significant Bit

16 (Group 1)	15	16	ECM 1	Most Significant Bit
	14	16	ECM 1	
	13	16	ECM 1	
	12	16	ECM 1	
	11	16	ECM 1	
	10	16	ECM 1	
	09	16	ECM 1	
	08	16	ECM 1	Least Significant Bit
	07	17	ECM 2	
	06	17	ECM 2	
	05	17	ECM 2	
	04	17	ECM 2	
	03	17	ECM 2	
	02	17	ECM 2	
	01	17	ECM 2	
	00	17	ECM 2	Least Significant Bit
14 (Group 2)	15	18	Roll Rate	Most Significant Bit
	14	18	Roll Rate	
	13	18	Roll Rate	
	12	18	Roll Rate	
	11	18	Roll Rate	
	10	18	Roll Rate	

	09	18	Roll Rate	
	08	18	Roll Rate	
	07	18	Roll Rate	
	06	18	Roll Rate	Least Significant Bit
	05	19	Yaw Rate	Most Significant Bit
	04	19	Yaw Rate	
	03	19	Yaw Rate	
	02	19	Yaw Rate	
	01	19	Yaw Rate	
	00	19	Yaw Rate	
15 (Group 2)	15	19	Yaw Rate	
	14	19	Yaw Rate	
	13	19	Yaw Rate	
	12	19	Yaw Rate	Least Significant Bit
	11	20	Recovery Battery Voltage	Most Significant Bit
	10	20	Recovery Battery Voltage	
	09	20	Recovery Battery Voltage	
	08	20	Recovery Battery Voltage	Least Significant Bit
	07	21	Pitch Rate	Most Significant Bit
	06	21	Pitch Rate	
	05	21	Pitch Rate	

	04	21	Pitch Rate	
	03	21	Pitch Rate	
	02	21	Pitch Rate	
	01	21	Pitch Rate	
	00	21	Pitch Rate	Least Significant Bit
16 (Group 2)	15	22	PRC 2 Wrap - Pitch/NZ Command	Most Significant Bit
	14	22	PRC 2 Wrap - Pitch/NZ Command	
	13	22	PRC 2 Wrap - Pitch/NZ Command	
	12	22	PRC 2 Wrap - Pitch/NZ Command	
	11	22	PRC 2 Wrap - Pitch/NZ Command	
	10	22	PRC 2 Wrap - Pitch/NZ Command	
	09	22	PRC 2 Wrap - Pitch/NZ Command	
	08	22	PRC 2 Wrap - Pitch/NZ Command	Least Significant Bit
	07	23	PRC 1 Wrap - Roll Command	Most Significant Bit
	06	23	PRC 1 Wrap - Roll Command	
	05	23	PRC 1 Wrap - Roll Command	
	04	23	PRC 1 Wrap - Roll Command	

	03	23	PRC 1 Wrap - Roll Command	
	02	23	PRC 1 Wrap - Roll Command	
	01	23	PRC 1 Wrap - Roll Command	
	00	23	PRC 1 Wrap - Roll Command	Least Significant Bit
14 (Group 3)	15	24	Engine RPM	Most Significant Bit
	14	24	Engine RPM	
	13	24	Engine RPM	
	12	24	Engine RPM	
	11	24	Engine RPM	
	10	24	Engine RPM	
	09	24	Engine RPM	
	08	24	Engine RPM	Least Significant Bit
	07	25	Pendulum Angle	
	06	25	Pendulum Angle	
	05	25	Pendulum Angle	
	04	25	Pendulum Angle	
	03	25	Pendulum Angle	
	02	25	Pendulum Angle	
	01	25	Pendulum Angle	
	00	25	Pendulum Angle	Least Significant Bit

15 (Group 3)	15	26	PRC 5 Wrap - Throttle Command	Most Significant Bit
	14	26	PRC 5 Wrap - Throttle Command	
	13	26	PRC 5 Wrap - Throttle Command	
	12	26	PRC 5 Wrap - Throttle Command	
	11	26	PRC 5 Wrap - Throttle Command	
	10	26	PRC 5 Wrap - Throttle Command	
	09	26	PRC 5 Wrap - Throttle Command	
	08	26	PRC 5 Wrap - Throttle Command	Least Significant Bit
	07	27	Center Tank Fuel	
	06	27	Center Tank Fuel	
	05	27	Center Tank Fuel	
	04	27	Center Tank Fuel	
	03	27	Center Tank Fuel	
	02	27	Center Tank Fuel	
	01	27	Center Tank Fuel	
	00	27	Center Tank Fuel	Least Significant Bit
16 (Group 3)	15	28	Fuel Flow Rate	Most Significant Bit
	14	28	Fuel Flow Rate	

	13	28	Fuel Flow Rate	
	12	28	Fuel Flow Rate	
	11	28	Fuel Flow Rate	
	10	28	Fuel Flow Rate	
	09	28	Fuel Flow Rate	
	08	28	Fuel Flow Rate	
	07	28	Fuel Flow Rate	
	06	28	Fuel Flow Rate	Least Significant Bit
	05	29	Spare	
	04	29	Spare	
	03	29	Spare	
	02	29	Spare	
	01	29	Spare	
	00	29	Spare	

Appendix E - VFu MQM-107E Drone Frame (Uplink)

VFu MQM-107E Drone Frame Discrete Commands				
Word	**Bit**	**DIC**	**Name**	**Comments**
4	15	01	Payload 1	
	14	02	Payload 2	
	13	03	Payload 3	
	12	04	Payload 4	
	11	05	Payload 5	
	10	06	Payload 6	
	09	07	Payload 7	
	08	08	Payload 8	
	07	09	Payload 9	
	06	10	Payload 10	
	05	11	Spare	
	04	12	Spare	
	03	13	Spare	
	02	14	Spare	
	01	15	Payload 11	
	00	16	Payload 12	
5	15	17	Datalink Valid	
	14	18	Spare	
	13	19	Payload 13	
	12	20	Heading Hold Override	

	11	21	Payload 14	
	10	22	Payload 15	
	09	23	Delta G	
	08	24	Payload 16	
	07	25	Recovery in Progress	
	06	26	Slice Select	
	05	27	Spare	
	04	28	Spare	
	03	29	Spare	
	02	30	Spare	
	01	31	Pitchback Select	
	00	32	Spare	
6	15	33	Escape Start	
	14	34	Escape Complete	
	13	35	Spare	
	12	36	Spare	
	11	37	Roll Erection/Heading Hold	
	10	38	Emergency Main Chute	
	09	39	Level Flight	
	08	40	Drogue Deploy	
	07	41	High G	
	06	42	Engine Kill	
	05	43	Spare	
	04	44	Spare	

	03	45	Emergency Recovery Arm	
	02	46	Pitch Over	
	01	47	Spare	
	00	48	Spare	
7	15	49	Scoring On	
	14	50	Pitch Command Rate Limit	
	13	51	Spare	
	12	52	Baro Altitude Hold	
	11	53	Smoke	
	10	54	Airspeed Mode	
	09	55	Payload Arm	
	08	56	Spare	
	07	57	Spare	
	06	58	Spare	
	05	59	Spare	
	04	60	Spare	
	03	61	Spare	
	02	62	Spare	
	01	63	Spare	
	00	64	Spare	

VFu MQM-107E Drone Frame Proportional Commands				
Word	**Bit**	**PRC**	**Name**	**Comments**
8	15	01	Roll	Most Significant Bit
	14	01	Roll	
	13	01	Roll	
	12	01	Roll	
	11	01	Roll	
	10	01	Roll	
	09	01	Roll	
	08	01	Roll	
	07	01	Roll	
	06	01	Roll	Least Significant Bit
	05	02	Pitch NZ	Most Significant Bit
	04	02	Pitch NZ	NZ Cmd when DIC(41).
	03	02	Pitch NZ	
	02	02	Pitch NZ	
	01	02	Pitch NZ	
	00	02	Pitch NZ	
9	15	02	Pitch NZ	
	14	02	Pitch NZ	
	13	02	Pitch NZ	
	12	02	Pitch NZ	Least Significant Bit

	11	03	Radar Altitude	Most Significant Bit
	10	03	Radar Altitude	
	09	03	Radar Altitude	
	08	03	Radar Altitude	
	07	03	Radar Altitude	
	06	03	Radar Altitude	
	05	03	Radar Altitude	
	04	03	Radar Altitude	
	03	03	Radar Altitude	
	02	03	Radar Altitude	Least Significant Bit
	01	04	Escape Roll	Most Significant Bit
	00	04	Escape Roll	
10	15	04	Escape Roll	
	14	04	Escape Roll	
	13	04	Escape Roll	
	12	04	Escape Roll	
	11	04	Escape Roll	
	10	04	Escape Roll	
	09	04	Escape Roll	
	08	04	Escape Roll	Least Significant Bit
	07	05	Throttle	Most Significant Bit
	06	05	Throttle	
	05	05	Throttle	
	04	05	Throttle	

	03	05	Throttle	
	02	05	Throttle	
	01	05	Throttle	
	00	05	Throttle	
11	15	05	Throttle	
	14	05	Throttle	Least Significant Bit
	13	06	Spare (LATS)	Most Significant Bit
	12	06	Spare (LATS)	
	11	06	Spare (LATS)	
	10	06	Spare (LATS)	
	09	06	Spare (LATS)	
	08	06	Spare (LATS)	
	07	06	Spare (LATS)	
	06	06	Spare (LATS)	
	05	06	Spare (LATS)	
	04	06	Spare (LATS)	Least Significant Bit
	03	07	Spare	Most Significant Bit
	02	07	Spare	
	01	07	Spare	
	00	07	Spare	
12	15	07	Spare	
	14	07	Spare	
	13	07	Spare	

	12	07	Spare	
	11	07	Spare	
	10	07	Spare	Least Significant Bit
	09	08	Escape Roll Bias	Most Significant Bit
	08	08	Escape Roll Bias	
	07	08	Escape Roll Bias	
	06	08	Escape Roll Bias	
	05	08	Escape Roll Bias	
	04	08	Escape Roll Bias	
	03	08	Escape Roll Bias	
	02	08	Escape Roll Bias	
	01	08	Escape Roll Bias	
	00	08	Escape Roll Bias	Least Significant Bit

Appendix F - VFd MQM-107E Drone Frame (Downlink)

VFd MQM-107E Drone Frame Discrete Telemetry				
Word	**Bit**	**DIT**	**Name**	**Comments**
3	15	01	Payload 1	
	14	02	Payload 2	
	13	03	Payload 3	
	12	04	Payload 4	
	11	05	Payload 5	
	10	06	Payload 6	
	09	07	Payload 7	
	08	08	Payload 8	
	07	09	Payload 9	
	06	10	Payload 10	
	05	11	Radar Altitude Invalid	
	04	12	Oil Pressure Low	
	03	13	Spare	
	02	14	Spare	
	01	15	Payload 11	
	00	16	Payload 12	
4	15	17	Datalink Valid	
	14	18	Zero Time	
	13	19	Payload 13	
	12	20	Heading Hold Override	
	11	21	Payload 14	

	10	22	Payload 15	
	09	23	Delta G	
	08	24	Payload 16	
	07	25	Recovery in Progress	
	06	26	Slice Select	
	05	27	Spare	
	04	28	Spare	
	03	29	Spare	
	02	30	DAP Valid/Clock	
	01	31	Pitchback Select	
	00	32	Spare	
5	15	33	Escape Start	
	14	34	Escape Complete	
	13	35	Spare	
	12	36	Spare	
	11	37	Roll Erection/Heading Hold	
	10	38	Emergency Main Chute	
	09	39	Level Flight	
	08	40	Drogue Deploy	
	07	41	High G	
	06	42	Engine Kill	
	05	43	Spare	
	04	44	Spare	
	03	45	Emergency Recovery	

			Arm	
	02	46	Pitch Over	
	01	47	Spare	
	00	48	Spare	
6	15	49	Scoring On	
	14	50	Pitch Rate Limit Active	
	13	51	Spare	
	12	52	Baro Altitude Hold	
	11	53	Smoke	
	10	54	Airspeed Mode	
	09	55	Payload Arm	
	08	56	Spare	
	07	57	Status Code 8	
	06	58	Status Code 7	
	05	59	Status Code 6	
	04	60	Status Code 5	
	03	61	Status Code 4	
	02	62	Status Code 3	
	01	63	Status Code 2	
	00	64	Status Code 1	

VFd MQM-107E Drone Frame Proportional Telemetry				
Word	**Bit**	**PRT**	**Name**	**Comments**
7	15	01	Rudder Position	Most Significant Bit
	14	01	Rudder Position	
	13	01	Rudder Position	
	12	01	Rudder Position	
	11	01	Rudder Position	
	10	01	Rudder Position	
	09	01	Rudder Position	
	08	01	Rudder Position	Least Significant Bit
	07	02	Elevator Position	Most Significant Bit
	06	02	Elevator Position	
	05	02	Elevator Position	
	04	02	Elevator Position	
	03	02	Elevator Position	
	02	02	Elevator Position	
	01	02	Elevator Position	
	00	02	Elevator Position	Least Significant Bit
8	15	03	Aileron Position	
	14	03	Aileron Position	
	13	03	Aileron Position	
	12	03	Aileron Position	
	11	03	Aileron Position	

	10	03	Aileron Position	
	09	03	Aileron Position	
	08	03	Aileron Position	Least Significant Bit
	07	04	Indicated Airspeed	
	06	04	Indicated Airspeed	
	05	04	Indicated Airspeed	
	04	04	Indicated Airspeed	
	03	04	Indicated Airspeed	
	02	04	Indicated Airspeed	
	01	04	Indicated Airspeed	
	00	04	Indicated Airspeed	
9	15	04	Indicated Airspeed	
	14	04	Indicated Airspeed	
	13	04	Indicated Airspeed	
	12	04	Indicated Airspeed	Least Significant Bit
	11	05	Barometric Altitude	Most Significant Bit
	10	05	Barometric Altitude	
	09	05	Barometric Altitude	
	08	05	Barometric Altitude	
	07	05	Barometric Altitude	
	06	05	Barometric Altitude	
	05	05	Barometric Altitude	
	04	05	Barometric Altitude	
	03	05	Barometric Altitude	

	02	05	Barometric Altitude	
	01	05	Barometric Altitude	
	00	05	Barometric Altitude	Least Significant Bit
10	15	06	Baro/Radar Altitude Error	Most Significant Bit
	14	06	Baro/Radar Altitude Error	
	13	06	Baro/Radar Altitude Error	
	12	06	Baro/Radar Altitude Error	
	11	06	Baro/Radar Altitude Error	
	10	06	Baro/Radar Altitude Error	
	09	06	Baro/Radar Altitude Error	
	08	06	Baro/Radar Altitude Error	
	07	06	Baro/Radar Altitude Error	
	06	06	Baro/Radar Altitude Error	
	05	06	Baro/Radar Altitude Error	
	04	06	Baro/Radar Altitude Error	Least Significant Bit
	03	07	Radar Altitude	Most Significant Bit
	02	07	Radar Altitude	
	01	07	Radar Altitude	

	00	07	Radar Altitude	
11	15	07	Radar Altitude	
	14	07	Radar Altitude	
	13	07	Radar Altitude	
	12	07	Radar Altitude	
	11	07	Radar Altitude	
	10	07	Radar Altitude	
	09	07	Radar Altitude	
	08	07	Radar Altitude	Least Significant Bit
	07	08	Normal Acceleration	Most Significant Bit
	06	08	Normal Acceleration	
	05	08	Normal Acceleration	
	04	08	Normal Acceleration	
	03	08	Normal Acceleration	
	02	08	Normal Acceleration	
	01	08	Normal Acceleration	
	00	08	Normal Acceleration	
12	15	08	Normal Acceleration	
	14	08	Normal Acceleration	Least Significant Bit
	13	09	Roll Angle	Most Significant Bit
	12	09	Roll Angle	
	11	09	Roll Angle	
	10	09	Roll Angle	

	09	09	Roll Angle	
	08	09	Roll Angle	
	07	09	Roll Angle	
	06	09	Roll Angle	
	05	09	Roll Angle	
	04	09	Roll Angle	Least Significant Bit
	03	10	Filtered Heading	Most Significant Bit
	02	10	Filtered Heading	
	01	10	Filtered Heading	
	00	10	Filtered Heading	
13	15	10	Filtered Heading	
	14	10	Filtered Heading	
	13	10	Filtered Heading	
	12	10	Filtered Heading	
	11	10	Filtered Heading	
	10	10	Filtered Heading	Least Significant Bit
	09	11	Pitch Angle	Most Significant Bit
	08	11	Pitch Angle	
	07	11	Pitch Angle	
	06	11	Pitch Angle	
	05	11	Pitch Angle	
	04	11	Pitch Angle	
	03	11	Pitch Angle	
	02	11	Pitch Angle	

	01	11	Pitch Angle	
	00	11	Pitch Angle	Least Significant Bit
14 (Group 1)	15	12	Airspeed Error	Most Significant Bit
	14	12	Airspeed Error	
	13	12	Airspeed Error	
	12	12	Airspeed Error	
	11	12	Airspeed Error	
	10	12	Airspeed Error	
	09	12	Airspeed Error	
	08	12	Airspeed Error	Least Significant Bit
	07	13	Cross Coupling	Most Significant Bit
	06	13	Cross Coupling	
	05	13	Cross Coupling	
	04	13	Cross Coupling	
	03	13	Cross Coupling	
	02	13	Cross Coupling	
	01	13	Cross Coupling	
	00	13	Cross Coupling	Least Significant Bit
15 (Group 1)	15	14	PRC 3 Wrap/Radar Alt. Cmd.	Most Significant Bit
	14	14	PRC 3 Wrap/Radar Alt. Cmd.	
	13	14	PRC 3 Wrap/Radar Alt.	

			Cmd.	
	12	14	PRC 3 Wrap/Radar Alt. Cmd.	
	11	14	PRC 3 Wrap/Radar Alt. Cmd.	
	10	14	PRC 3 Wrap/Radar Alt. Cmd.	
	09	14	PRC 3 Wrap/Radar Alt. Cmd.	
	08	14	PRC 3 Wrap/Radar Alt. Cmd.	Least Significant Bit
	07	15	Exhaust Gas Temperature	Most Significant Bit
	06	15	Exhaust Gas Temperature	EGT
	05	15	Exhaust Gas Temperature	
	04	15	Exhaust Gas Temperature	
	03	15	Exhaust Gas Temperature	
	02	15	Exhaust Gas Temperature	
	01	15	Exhaust Gas Temperature	
	00	15	Exhaust Gas Temperature	Least Significant Bit
16 (Group 1)	15	16	Spare 1	Most Significant Bit
	14	16	Spare 1	

	13	16	Spare 1	
	12	16	Spare 1	
	11	16	Spare 1	
	10	16	Spare 1	
	09	16	Spare 1	
	08	16	Spare 1	Least Significant Bit
	07	17	Spare 2	Most Significant Bit
	06	17	Spare 2	
	05	17	Spare 2	
	04	17	Spare 2	
	03	17	Spare 2	
	02	17	Spare 2	
	01	17	Spare 2	
	00	17	Spare 2	Least Significant Bit
14 (Group 2)	15	18	Roll Rate	Most Significant Bit
	14	18	Roll Rate	
	13	18	Roll Rate	
	12	18	Roll Rate	
	11	18	Roll Rate	
	10	18	Roll Rate	
	09	18	Roll Rate	
	08	18	Roll Rate	
	07	18	Roll Rate	

	06	18	Roll Rate	Least Significant Bit
	05	19	Yaw Rate	Most Significant Bit
	04	19	Yaw Rate	
	03	19	Yaw Rate	
	02	19	Yaw Rate	
	01	19	Yaw Rate	
	00	19	Yaw Rate	
15 (Group 2)	15	19	Yaw Rate	
	14	19	Yaw Rate	
	13	19	Yaw Rate	
	12	19	Yaw Rate	Least Significant Bit
	11	20	Recovery Battery Voltage	Most Significant Bit
	10	20	Recovery Battery Voltage	
	09	20	Recovery Battery Voltage	
	08	20	Recovery Battery Voltage	Least Significant Bit
	07	21	Pitch Rate	Most Significant Bit
	06	21	Pitch Rate	
	05	21	Pitch Rate	
	04	21	Pitch Rate	
	03	21	Pitch Rate	
	02	21	Pitch Rate	

	01	21	Pitch Rate	
	00	21	Pitch Rate	Least Significant Bit
16 (Group 2)	15	22	PRC 2 Wrap - Pitch/NZ Command	Most Significant Bit
	14	22	PRC 2 Wrap - Pitch/NZ Command	
	13	22	PRC 2 Wrap - Pitch/NZ Command	
	12	22	PRC 2 Wrap - Pitch/NZ Command	
	11	22	PRC 2 Wrap - Pitch/NZ Command	
	10	22	PRC 2 Wrap - Pitch/NZ Command	
	09	22	PRC 2 Wrap - Pitch/NZ Command	
	08	22	PRC 2 Wrap - Pitch/NZ Command	Least Significant Bit
	07	23	PRC 1 Wrap - Roll Command	Most Significant Bit
	06	23	PRC 1 Wrap - Roll Command	
	05	23	PRC 1 Wrap - Roll Command	
	04	23	PRC 1 Wrap - Roll Command	
	03	23	PRC 1 Wrap - Roll Command	
	02	23	PRC 1 Wrap - Roll Command	

	01	23	PRC 1 Wrap - Roll Command	
	00	23	PRC 1 Wrap - Roll Command	Least Significant Bit
14 (Group 3)	15	24	Engine RPM	Most Significant Bit
	14	24	Engine RPM	
	13	24	Engine RPM	
	12	24	Engine RPM	
	11	24	Engine RPM	
	10	24	Engine RPM	
	09	24	Engine RPM	
	08	24	Engine RPM	Least Significant Bit
	07	25	Spare	Most Significant Bit
	06	25	Spare	
	05	25	Spare	
	04	25	Spare	
	03	25	Spare	
	02	25	Spare	
	01	25	Spare	
	00	25	Spare	Least Significant Bit
15 (Group 3)	15	26	Throttle Command	Most Significant Bit
	14	26	Throttle Command	

	13	26	Throttle Command	
	12	26	Throttle Command	
	11	26	Throttle Command	
	10	26	Throttle Command	
	09	26	Throttle Command	
	08	26	Throttle Command	Least Significant Bit
	07	27	Center Tank Fuel	Most Significant Bit
	06	27	Center Tank Fuel	
	05	27	Center Tank Fuel	
	04	27	Center Tank Fuel	
	03	27	Center Tank Fuel	
	02	27	Center Tank Fuel	
	01	27	Center Tank Fuel	
	00	27	Center Tank Fuel	Least Significant Bit
16 (Group 3)	15	28	Fuel Flow Rate	Most Significant Bit
	14	28	Fuel Flow Rate	
	13	28	Fuel Flow Rate	
	12	28	Fuel Flow Rate	
	11	28	Fuel Flow Rate	
	10	28	Fuel Flow Rate	
	09	28	Fuel Flow Rate	
	08	28	Fuel Flow Rate	
	07	28	Fuel Flow Rate	

	06	28	Fuel Flow Rate	Least Significant Bit
	05	29	Spare	Most Significant Bit
	04	29	Spare	
	03	29	Spare	
	02	29	Spare	
	01	29	Spare	
	00	29	Spare	

Appendix G - VFu BQM-34A Drone Frame (Uplink)

VFu BQM-34A Drone Frame Discrete Command

Word	**Bit**	**DIC**	**Name**	**Comments**
3	15	01	Thrust Increase	
	14	02	Thrust Decrease	
	13	03	Smoke On	
	12	04	Heading Trim - Left	
	11	05	Heading Trim - Right	
	10	06	Chaff/Flare Dispense - Left	
	09	07	Chaff/Flare Dispense - Right	
	08	08	Chaff/Flare Dispense - Reset	
	07	09	Radar Augment	
	06	10	Straight and Level	
	05	11	Autopilot Reset	
	04	12	Emergency Chute	
	03	13	CIR Pod On - Left	
	02	14	CIR Pod Off - Right	
	01	15	Accelerate	
	00	16	Turn - Right	
4	15	17	Command Chute	
	14	18	Climb	
	13	19	Dive	

	12	20	Turn - Left	
	11	21	Roll Arm	
	10	22	Roll Disarm	
	09	23	Scoring Calibrate	
	08	24	CIR Pods Off	
	07	25	Payload Arm	
	06	26	Payload 10	
	05	27	Maneuver Turn Arm	
	04	28	Low Altitude Control Off	
	03	29	Altitude Trim Up	
	02	30	Altitude Trim Down	
	01	31	Low Altitude Control On	
	00	32	Fuel Dump Disable	
5	15	33	High G Arm	
	14	34	Low Altitude Ctl. Normal Scale	
	13	35	Low Altitude Ctl. Expand Scale	
	12	36	Scoring Off	
	11	37	Scoring On	
	10	38	Spare	
	09	39	Spare	
	08	40	Spare	
	07	41	Spare	

	06	42	Spare	
	05	43	Spare	
	04	44	Spare	
	03	45	Spare	
	02	46	Spare	
	01	47	Spare	
	00	48	Spare	
6	15	49	Spare	
	14	50	Spare	
	13	51	Spare	
	12	52	Spare	
	11	53	Spare	
	10	54	Spare	
	09	55	Spare	
	08	56	Spare	
	07	57	Spare	
	06	58	Plume On - Left	
	05	59	Plume On - Right	
	04	60	Plume Off	
	03	61	Spare	
	02	62	Spare	
	01	63	Spare	
	00	64	Spare	

Appendix H - VFd BQM-34A Drone Frame (Downlink)

VFd BQM-34A Drone Frame Discrete Telemetry				
Word	**Bit**	**DIT**	**Name**	**Comments**
3	15	01	Thrust Increase	
	14	02	Thrust Decrease	
	13	03	Smoke On	
	12	04	Heading Trim - Left	
	11	05	Heading Trim - Right	
	10	06	Chaff/Flare Dispense - Left	
	09	07	Chaff/Flare Dispense - Right	
	08	08	Chaff/Flare Dispense - Reset	
	07	09	Radar Augment	
	06	10	Straight and Level	
	05	11	Autopilot Reset	
	04	12	Emergency Chute	
	03	13	CIR Pod On - Left	
	02	14	CIR Pod On - Right	
	01	15	Accelerate	
	00	16	Turn - Right	
4	15	17	Command Chute	
	14	18	Climb	
	13	19	Dive	

	12	20	Turn - Left	
	11	21	Roll Arm	
	10	22	Roll Disarm	
	09	23	Scoring Calibrate	
	08	24	CIR Pods Off	
	07	25	Payload Arm	
	06	26	Payload 10	
	05	27	Maneuver Turn Arm	
	04	28	Low Altitude Control Off	
	03	29	Altitude Trim Up	
	02	30	Altitude Trim Down	
	01	31	Chaff/Flare Dispense Active	
	00	32	Fuel Dump Disable	
5	15	33	High G Arm	
	14	34	Low Altitude Ctl. Normal Scale	
	13	35	Low Altitude Ctl. Expand Scale	
	12	36	Scoring Off	
	11	37	Scoring On	
	10	38	Release Mode	
	09	39	Baro Altitude < 5000 Feet	
	08	40	In Roll Mode	
	07	41	Low Fuel	

	06	42	Gyro Fail	
	05	43	Glide Mode	
	04	44	Command Lockout	
	03	45	Spare	
	02	46	Spare	
	01	47	Spare	
	00	48	Spare	
6	15	49	Spare	
	14	50	Spare	
	13	51	Spare	
	12	52	Spare	
	11	53	Spare	
	10	54	Spare	
	09	55	Spare	
	08	56	Spare	
	07	57	Spare	
	06	58	Plume On - Left	
	05	59	Plume On - Right	
	04	60	Plume Off	
	03	61	Spare	
	02	62	Spare	
	01	63	Escape Start	
	00	64	Escape Complete	

Appendix I - VFu M-47 Tank Frame (Uplink)

Discrete commands.

VFu M-47 Drone Frame Discrete Commands				
Word	**Bit**	**DIC**	**Name**	**Comments**
3	15	01	Speed Hold	
	14	02	Heading Hold	
	13	03	Engage/Stop	
	12	04	Abort Off/On	
	11	05	Gyro Power	
	10	06	Brakes	
	09	07	Spare	
	08	08	Spare	
	07	09	Spare	
	06	10	Spare	
	05	11	Spare	
	04	12	Spare	
	03	13	Spare	
	02	14	Spare	
	01	15	Spare	
	00	16	Spare	

Proportional commands.

VFu M-47 Tank Frame Proportional Commands				
Word	**Bit**	**DIT**	**Name**	**Comments**
4	15	01	Heading/Actuator Position	Most Significant Bit
	14	01	Heading/Actuator Position	
	13	01	Heading/Actuator Position	
	12	01	Heading/Actuator Position	
	11	01	Heading/Actuator Position	
	10	01	Heading/Actuator Position	
	09	01	Heading/Actuator Position	
	08	01	Heading/Actuator Position	
	07	01	Heading/Actuator Position	
	06	01	Heading/Actuator Position	
	05	01	Heading/Actuator Position	
	04	01	Heading/Actuator Position	
	03	01	Heading/Actuator Position	
	02	01	Heading/Actuator	

			Position	
	01	01	Heading/Actuator Position	
	00	01	Heading/Actuator Position	Least Significant Bit
5	15	02	Speed/RPM	Most Significant Bit
	14	02	Speed/RPM	
	13	02	Speed/RPM	
	12	02	Speed/RPM	
	11	02	Speed/RPM	
	10	02	Speed/RPM	
	09	02	Speed/RPM	
	08	02	Speed/RPM	
	07	02	Speed/RPM	
	06	02	Speed/RPM	
	05	02	Speed/RPM	
	04	02	Speed/RPM	
	03	02	Speed/RPM	
	02	02	Speed/RPM	
	01	02	Speed/RPM	
	00	02	Speed/RPM	Least Significant Bit

Appendix J - VFd M-47 Tank Frame (Downlink)

Discrete telemetry.

VFd M-47 Drone Frame Discrete Telemetry				
Word	**Bit**	**DIT**	**Name**	**Comments**
3	15	01	Right Steer Limit	
	14	02	Left Steer Limit	
	13	03	Throttle Minimum Limit	
	12	04	Throttle Maximum Limit	
	11	05	Brake Off Limit	
	10	06	Brake On Limit	
	09	07	Remote Status	
	08	08	Datalink Present	
	07	09	Gyro Power On	
	06	10	Brake On	
	05	11	Speed Hold	
	04	12	Heading Hold	
	03	13	Abort Off	
	02	14	MTACS Engaged	
	01	15	Man On Tank	
	00	16	Spare	
4	15	17	Spare	
	14	18	Spare	
	13	19	Engine Warning	

	12	20	Spare	
	11	21	Escape in Progress	
	10	22	Commanded Escape	
	09	23	Escape Complete	
	08	24	Spare	
	07	25	Spare	
	06	26	Spare	
	05	27	Spare	
	04	28	Spare	
	03	29	Spare	
	02	30	Spare	
	01	31	Spare	
	00	32	Spare	

Proportional telemetry.

VFu M-47 Tank Frame Proportional Telemetry				
Word	**Bit**	**PRT**	**Name**	**Comments**
5	15	01	Speed	Most Significant Bit
	14	01	Speed	
	13	01	Speed	
	12	01	Speed	
	11	01	Speed	
	10	01	Speed	
	09	01	Speed	

	08	01	Speed	
	07	01	Speed	
	06	01	Speed	
	05	01	Speed	
	04	01	Speed	
	03	01	Speed	
	02	01	Speed	
	01	01	Speed	
	00	01	Speed	Least Significant Bit
6	15	02	RPM	Most Significant Bit
	14	02	RPM	
	13	02	RPM	
	12	02	RPM	
	11	02	RPM	
	10	02	RPM	
	09	02	RPM	
	08	02	RPM	
	07	02	RPM	
	06	02	RPM	
	05	02	RPM	
	04	02	RPM	
	03	02	RPM	
	02	02	RPM	
	01	02	RPM	

	00	02	RPM	Least Significant Bit
7	15	03	Heading	Most Significant Bit
	14	03	Heading	
	13	03	Heading	
	12	03	Heading	
	11	03	Heading	
	10	03	Heading	
	09	03	Heading	
	08	03	Heading	
	07	03	Heading	
	06	03	Heading	
	05	03	Heading	
	04	03	Heading	
	03	03	Heading	
	02	03	Heading	
	01	03	Heading	
	00	03	Heading	Least Significant Bit
8	15	04	Actuator Position	Most Significant Bit
	14	04	Actuator Position	
	13	04	Actuator Position	
	12	04	Actuator Position	
	11	04	Actuator Position	
	10	04	Actuator Position	

	09	04	Actuator Position	
	08	04	Actuator Position	
	07	04	Actuator Position	
	06	04	Actuator Position	
	05	04	Actuator Position	
	04	04	Actuator Position	
	03	04	Actuator Position	
	02	04	Actuator Position	
	01	04	Actuator Position	
	00	04	Actuator Position	Least Significant Bit
9	15	05	PRC 1	Most Significant Bit
	14	05	PRC 1	
	13	05	PRC 1	
	12	05	PRC 1	
	11	05	PRC 1	
	10	05	PRC 1	
	09	05	PRC 1	
	08	05	PRC 1	
	07	05	PRC 1	
	06	05	PRC 1	
	05	05	PRC 1	
	04	05	PRC 1	
	03	05	PRC 1	
	02	05	PRC 1	

	01	05	PRC 1	
	00	05	PRC 1	Least Significant Bit
10	15	06	PRC 2	Most Significant Bit
	14	06	PRC 2	
	13	06	PRC 2	
	12	06	PRC 2	
	11	06	PRC 2	
	10	06	PRC 2	
	09	06	PRC 2	
	08	06	PRC 2	
	07	06	PRC 2	
	06	06	PRC 2	
	05	06	PRC 2	
	04	06	PRC 2	
	03	06	PRC 2	
	02	06	PRC 2	
	01	06	PRC 2	
	00	06	PRC 2	Least Significant Bit
11	15	07	Battery Voltage	Most Significant Bit
	14	07	Battery Voltage	
	13	07	Battery Voltage	
	12	07	Battery Voltage	
	11	07	Battery Voltage	

	10	07	Battery Voltage	
	09	07	Battery Voltage	
	08	07	Battery Voltage	
	07	07	Battery Voltage	
	06	07	Battery Voltage	
	05	07	Battery Voltage	
	04	07	Battery Voltage	
	03	07	Battery Voltage	
	02	07	Battery Voltage	
	01	07	Battery Voltage	
	00	07	Battery Voltage	Least Significant Bit
12	15	08	Heading Rate	Most Significant Bit
	14	08	Heading Rate	
	13	08	Heading Rate	
	12	08	Heading Rate	
	11	08	Heading Rate	
	10	08	Heading Rate	
	09	08	Heading Rate	
	08	08	Heading Rate	
	07	08	Heading Rate	
	06	08	Heading Rate	
	05	08	Heading Rate	
	04	08	Heading Rate	
	03	08	Heading Rate	

	02	08	Heading Rate	
	01	08	Heading Rate	
	00	08	Heading Rate	Least Significant Bit
13	15	09	Escape Indicator	
	14	09	Escape Indicator	
	13	09	Escape Indicator	
	12	09	Escape Indicator	
	11	09	Escape Indicator	
	10	09	Escape Indicator	
	09	09	Escape Indicator	
	08	09	Escape Indicator	
	07	09	Escape Indicator	
	06	09	Escape Indicator	
	05	09	Escape Indicator	
	04	09	Escape Indicator	
	03	09	Escape Indicator	
	02	09	Escape Indicator	
	01	09	Escape Indicator	
	00	09	Escape Indicator	Least Significant Bit
14	15	10	Spare	Most Significant Bit
	14	10	Spare	
	13	10	Spare	
	12	10	Spare	

	11	10	Spare	
	10	10	Spare	
	09	10	Spare	
	08	10	Spare	
	07	10	Spare	
	06	10	Spare	
	05	10	Spare	
	04	10	Spare	
	03	10	Spare	
	02	10	Spare	
	01	10	Spare	
	00	10	Spare	

APPENDIX B- WSMR DATA LINK ENHANCEMENTS

1.0 Scope

This document presents White Sands Missile Range (WSMR) enhancements and fixes to the Gulf Range Drone Control Upgrade System (GRDCUS) data link format. It contains very minor corrections to the revision level stated of the referenced document, but is intended only to augment that document. The changes were made by Coleman Research Corporation to support ground targets, the QF-4 and eventually other aerial targets.

This document also describes the content of the ground target (tank) uplink and downlink. These have been augmented for additional types of ground targets beyond the original M-47, and for improved functionality. It also describes the QF-4 compatible Unit Test uplink and downlink, which were added for both ground targets and the F-100 (track-only) Vehicle Borne Subsystem (VBS) firmware.

This is Revision 2 of this document. The original document covered only the changes to add SNR's to the IS messages and the minor IS corrections and enhancements. Revision 1 added the ground target and track-only message formats. This revision contains only minor changes in the ground target proportional telemetry and corrects a few typographical errors.

2.0 Applicable Documents

GRDCUS Data Link Message Format Specification
Date Revised: 11 March 1991

3.0 Description

The enhancements to the ground station data link format were made as an aid in evaluation of the quality of the data link for site selection purposes. The primary change was in the addition of a signal-to-noise ratio (SNR) to the downlink for DLU sites only (the DLS has no hardware capability to read SNR). Minor changes were made to enhance or correct error status reporting by the ground stations. One additional change was the removal of code supporting the Flight Termination Transponder (FTT) uplink and downlink frames.

The SNR is read by each member of a Quad during each target response. The SNR is scaled by integer division by 8 (shift right 3 bits), and by limiting the value to a maximum of 15. The result is placed in the nibble (4 bits) corresponding to the order of target response and packed into the last word of the frame. The inclusion of the SNR is readily apparent to the ground control computer by the odd number of words in the frame. DLS sites do not return dummy SNR's; their frame lengths will always be even.

Bit 6 has been added to the relay status byte in the downlink to signify that there were more than three parity errors on the downlink from the master (or second relay, if used), but that a response was received.

Bit 0 of the slave status byte indicates a parity error on a downlink from a target. The latest revision (at WSMR) of the referenced document states that bit is spare.

Bit 0 of the slave's downlink status is also set if there was a parity error detected by the master site on the downlink from the slave to the master. This is a WSMR enhancement. The TOA invalid bit will also be set if the error occurred in one of the TOA words. This is a WSMR fix.

The FTT mode code has been removed from all site firmware. It appears there have been occasions when interference has been interpreted as FTT data links, and WSMR has no need for the FTT mode.

4.0 Message Format Description

The WSMR-modified message formats are described in the following tables. The tables are numbered and laid out to match those in the referenced document.

Table 9. Vfd DOWNLINK MESSAGE

word#	msb- -- -- -lsb	contents
		<- Vfd RELAY or MASTER FRAME->
Rn 1	ffff oooo llll llll (9xxx)	f = message type o = frame type l = flength
Rn 2	aaaa aaaa asss ssss	a = source address s = station status
Rn 3	aaaa aaaa avtt tttt	a = address v = data valid t = TOA
Rn 4	tttt tttt tttt tttt	t = TOA
Rn n	dddd dddd dddd dddd	d = n number address and TOA data words
Rn m	1111 2222 3333 4444	1 = target 1 SNR 2 = target 2 SNR, etc.
		<- Vfd SLAVE FRAME->
Rn 1	ffff oooo llll llll (9Axx)	f = message type o = frame type l = flength
Rn 2	aaaa aaaa asss ssss	a = source address s = station status
Rn 3	aaaa aaaa avtt tttt	a = address v = data valid t = TOA
Rn 4	tttt tttt tttt tttt	t = TOA
Rn n	dddd dddd dddd dddd	d = n number address and TOA data words
Rn m	1111 2222 3333 4444	1 = target 1 SNR 2 = target 2 SNR, etc.

Table 11. Vfd RELAY or MASTER FRAME

```
word#  msb- ---- ---- -lsb

Rn 1  ffff oooo llll llll
Rn 2  aaaa aaaa asss ssss
Rn 3  aaaa aaaa avtt tttt
Rn 4  tttt tttt tttt tttt
Rn n  dddd dddd dddd dddd
Rn m  1111 2222 3333 4444
```

ffff	Message type field. The message type for the GRDCUS downlink is 1001 binary.
oooo	The relay mode field. This field for the first relay (ISc) is as it originated from the ground control computer, Subsequent relay fields decrease by 1 until the master mode field, which will be 0001 binary.
llllllll	This 8 bit field is the frame length in 16-bit words. It will be an odd number IFF the SNR is included.
aaaaaaaaa	This first ‘a’ field is the source address of this station.
sssssss	This is the status field associated with this station. A one in bit 0 indicates a receive error in downlink traffic, bit 1 a receive error in uplink traffic, bIt 2 a POR, bit 3 a Microwave downlink error (ISc only), bit 4 a serial interface error (ISc only), and bit 6 over 3 errors on downlink traffic (relay only).
aaaaaaaaa	These subsequent ‘a’ fields are the addresses associated with adjacent TOA fields.
v	If this bit is 1, the following TOA is invalid.
tttttt	The most significant six bits of the TOA associated with the preceding address.
tttttttttttttttt	The least significant 16 bits of the TOA.
dddddddddddddddd	Words Rn 3 and Rn 4 are repeated for each participant for which a TOA is available
1111	SNR of downlink from first responder (not necessarily target 1).
2222	SNR of downlink from second responder (if applicable).
3333	SNR of downlink from third responder (if applicable).
4444	SNR of downlink from fourth responder (if applicable).

Table 16. Vfd SLAVE FRAME

```
word#  msb- ---- ---- -lsb

 Rn 1  ffff oooo llll llll
 Rn 2  aaaa aaaa asss ssss
 Rn 3  aaaa aaaa avtt tttt
 Rn 4  tttt tttt tttt tttt
 Rn n  dddd dddd dddd dddd
 Rn m  1111 2222 3333 4444
```

ffff	Message type field. The message type for the GRDCUS downlink is 1001 binary.
oooo	The slave mode field. This field will be 1010 binary.
llllllll	This 8 bit field is the frame length in 16-bit words. It will be an odd number IFF the SNR is included.
aaaaaaaaa	This first ‘a’ field is the source address of this station.
sssssss	This is the status field associated with this station. A one in bit 0 indicates a receive error in downlink traffic, bit 1 indicates a POR. The other bits are spares
aaaaaaaaa	These subsequent ‘a’ fields are the addresses associated with adjacent TOA fields.
v	If this bit is 1, the following TOA is invalid.
tttttt	The most significant six bits of the TOA associated with the preceding address.
tttttttttttttttt	The least significant 16 bits of the TOA.
dddddddddddddddd	Words Rn 3 and Rn 4 are repeated for each participant for which a TOA is available
1111	SNR of downlink from first responder (not necessarily target 1).
2222	SNR of downlink from second responder (if applicable).
3333	SNR of downlink from third responder (if applicable).
4444	SNR of downlink from fourth responder (if applicable).

Appendix A

<<- VFu Ground Target Data ->>

Ground Target Discrete Commands

Word #	Bit#	DIC#	DIC Name	Comments
Dn 4	15	1	Speed Hold	
	14	2	Heading Hold	
	13	3	Engage/Stop	
	12	4	Abort Off/On	
	11	5	Gyro Power On/Off	
	10	6	Brakes	
	9	7	Sim Carrier	
	8	8	Direct Throttle	PRC2 is throttle mvmt. cmd.
	7	9	Shift Command	Initiates VBS-Controlled Shift
	6	10	Spare	
	5	11	Spare	
	4	12	Spare	
	3	13	Spare	
	2	14	Spare	
	1	15	Debug TM	Currently Unused
	0	16	Simulator	Currently Unused
Dn 5	15	17	Spare	
	14	18	Spare	
	13	19	Spare	
	12	20	Spare	
	11	21	Spare	
	10	22	Spare	
	9	23	Spare	
	8	24	Spare	
	7	25	Gear 2	Usually Neutral Gear
	6	26	Clutch In/Out	
	5	27	Gear 3	Usually Higher Gear
	4	28	Gear 1	Low Gear
	3	29	Spare	
	2	30	Spare	
	1	31	Spare	
	0	32	Spare	

Ground Target Proportional Commands

Word #	Bit#	PRC#	PRC Name	Comments
Dn 6	15	1	Heading/Actuator Position	MSB
	14	1	Heading/Actuator Position	
	13	1	Heading/Actuator Position	
	12	1	Heading/Actuator Position	
	11	1	Heading/Actuator Position	
	10	1	Heading/Actuator Position	
	9	1	Heading/Actuator Position	
	8	1	Heading/Actuator Position	
	7	1	Heading/Actuator Position	
	6	1	Heading/Actuator Position	
	5	1	Heading/Actuator Position	
	4	1	Heading/Actuator Position	
	3	1	Heading/Actuator Position	
	2	1	Heading/Actuator Position	
	1	1	Heading/Actuator Position	
	0	1	Heading/Actuator Position	LSB
Dn 7	15	2	RPM/Throttle Movement	MSB
	14	2	RPM/Throttle Movement	

13	2	RPM/Throttle Movement	
12	2	RPM/Throttle Movement	
11	2	RPM/Throttle Movement	
10	2	RPM/Throttle Movement	
9	2	RPM/Throttle Movement	
8	2	RPM/Throttle Movement	
7	2	RPM/Throttle Movement	
6	2	RPM/Throttle Movement	
5	2	RPM/Throttle Movement	
4	2	RPM/Throttle Movement	
3	2	RPM/Throttle Movement	
2	2	RPM/Throttle Movement	
1	2	RPM/Throttle Movement	
0	2	RPM/Throttle Movement	LSB

Ground Target Proportional Commands (Continued)

Word #	Bit#	PRC#	PRC Name	Comments
Dn 8	15	3	Left Steer Point	MSB
	14	3	Left Steer Point	
	13	3	Left Steer Point	PRC 3 and 4 may be used to
	12	3	Left Steer Point	inform the VBS of the size of
	11	3	Left Steer Point	the steering dead zone, if known,
	10	3	Left Steer Point	or to over-ride the VBS value
	9	3	Left Steer Point	calculated internally. If PRC 3 is
	8	3	Left Steer Point	zero, both PRC 3 & 4 will be
	7	3	Left Steer Point	ignored by VBS. If PRC 3 is ,
	6	3	Left Steer Point	non-zero, PRC 4 MUST be non-
	5	3	Left Steer Point	zero.
	4	3	Left Steer Point	
	3	3	Left Steer Point	
	2	3	Left Steer Point	
	1	3	Left Steer Point	
	0	3	Left Steer Point	LSB
Dn 9	15	4	Right Steer Point	MSB
	14	4	Right Steer Point	
	13	4	Right Steer Point	
	12	4	Right Steer Point	
	11	4	Right Steer Point	
	10	4	Right Steer Point	
	9	4	Right Steer Point	
	8	4	Right Steer Point	
	7	4	Right Steer Point	
	6	4	Right Steer Point	
	5	4	Right Steer Point	
	4	4	Right Steer Point	
	3	4	Right Steer Point	
	2	4	Right Steer Point	
	1	4	Right Steer Point	
	0	4	Right Steer Point	LSB

Ground Target Proportional Commands (Conclusion)

Word #	Bit#	PRC#	PRC Name	Comments
Dn 10	15	5	High Gear RPM	MSB
	14	5	High Gear RPM	
	13	5	High Gear RPM	Value can be used to over-ride
	12	5	High Gear RPM	internal shifting algorithm
	11	5	High Gear RPM	RPM calculation in VBS for
	10	5	High Gear RPM	non-standard shifts. Value is
	9	5	High Gear RPM	correct RPM for synchronization
	8	5	High Gear RPM	of shift to high gear. This PRC
	7	5	High Gear RPM	has not been used, but is present
	6	5	High Gear RPM	to allow flexibility in remoting
	5	5	High Gear RPM	without firmware modifications.
	4	5	High Gear RPM	
	3	5	High Gear RPM	
	2	5	High Gear RPM	
	1	5	High Gear RPM	
	0	5	High Gear RPM	LSB

Appendix B

<<- VFu Unit Test Mode (Ground Target or F-100)->>
(from ground control computer)

Uplink Commands F-100 or Ground Target

Word#	Bit#	Data	Comments
Dn 1	15-0	0503	The mode and length for a Unit Test mode message
Dn 2	15-0	AADD	The address and delay will be of the same format as for the Command & Control message.
Dn 3	15-0	SSSS	This word will be the same as the Command & Control word Dn 3. The uplink antenna bits will be valid for F-100 only. No other commanded bits are valid.

Appendix C

<<- VFd Ground Target Data ->>

Ground Target Discrete Telemetry

Word #	Bit#	DIT#	DIT Name	Comments
Dn 3	15	1	Right Steer Limit	Rt Steer Full Off for Dual Steer
	14	2	Left Steer Limit	Rt Steer Full On for Dual Steer
	13	3	Throttle Min. Limit	
	12	4	Throttle Max. Limit	
	11	5	Brake Off Limit	
	10	6	Brake On Limit	
	9	7	Remote	Status of Operator Control Box
	8	8	Datalink Present	Hardware Wrap
	7	9	Gyro Power On	Hardware Wrap
	6	10	Brake On Command	Hardware Wrap
	5	11	Speed Hold	Firmware Wrap
	4	12	Heading Hold	Firmware Wrap
	3	13	Abort	Firmware Wrap
	2	14	Engaged	Firmware Wrap
	1	15	Tank Occupied	Operator On/Near Tank
	0	16	Spare	
Dn 4	15	17	Clutch In Limit	
	14	18	Clutch Out Limit	
	13	19	Clutch Command	Firmware Wrap
	12	20	Spare	
	11	21	Escape In Progress	Firmware Generated
	10	22	Escape Command	Firmware Wrap
	9	23	Escape Complete	Firmware Generated
	8	24	Spare	
	7	25	Spare	
	6	26	Gear Position 3	
	5	27	Gear Position 2	
	4	28	Gear Position 1	
	3	29	Left Steer Full Off	Dual Steer Only
	2	30	Left Steer Full On	Dual Steer Only
	1	31	Direct Throttle	Firmware Wrap

0	32	Shift Command	Firmware Wrap

Ground Target Discrete Telemetry (Conclusion)

Word #	Bit#	DIT#	DIT Name	Comments
Dn 5	15	33	Shift In Progress	Firmware Generated
	14	34	Shift Complete	Firmware Generated
	13	35	Left Actuator Mvt	Debug
	12	36	Right Actuator Mvt	Debug
	11	37	Steering Cal Done	Firmware Generated
	10	38	Spare	
	9	39	Spare	
	8	40	Spare	
	7	41	Spare	
	6	42	Spare	
	5	43	Spare	
	4	44	Spare	
	3	45	Spare	
	2	46	Spare	
	1	47	Spare	
	0	48	Spare	
Dn 6	15	49	Spare	Reserved
	14	50	Spare	Reserved
	13	51	Spare	Reserved
	12	52	Spare	Reserved
	11	53	Spare	Reserved
	10	54	Spare	Reserved
	9	55	Spare	Reserved
	8	56	Spare	Reserved
	7	57	Spare	Reserved
	6	58	Spare	Reserved
	5	59	Spare	Reserved
	4	60	Spare	Reserved
	3	61	Spare	
	2	62	Spare	
	1	63	Spare	
	0	64	Spare	

Ground Target Proportional Telemetry

Word #	Bit#	PRT#	PRT Name	Comments
Dn 7	15	1	Speed	MSB
	14	1	Speed	
	13	1	Speed	Not present for all target types
	12	1	Speed	Not present for all target types.
	11	1	Speed	Not present for all target types
	10	1	Speed	Not present for all target types.
	9	1	Speed	Not present for all target types
	8	1	Speed	Not present for all target types
	7	1	Speed	Not present for all target types
	6	1	Speed	Not present for all target types
	5	1	Speed	Not present for all target types
	4	1	Speed	Not present for all target types
	3	1	Speed	Not present for all target types
	2	1	Speed	Not present for all target types
	1	1	Speed	
	0	1	Speed	LSB
Dn 8	15	2	RPM	MSB
	14	2	RPM	
	13	2	RPM	
	12	2	RPM	
	11	2	RPM	
	10	2	RPM	
	9	2	RPM	
	8	2	RPM	
	7	2	RPM	

6	2	RPM	
5	2	RPM	
4	2	RPM	
3	2	RPM	
2	2	RPM	
1	2	RPM	
0	2	RPM	LSB

Ground Target Proportional Telemetry (Continued)

Word #	Bit#	PRT#	PRT Name	Comments
Dn 9	15	3	Heading	MSB
	14	3	Heading	
	13	3	Heading	
	12	3	Heading	
	11	3	Heading	
	10	3	Heading	
	9	3	Heading	
	8	3	Heading	
	7	3	Heading	
	6	3	Heading	
	5	3	Heading	
	4	3	Heading	
	3	3	Heading	
	2	3	Heading	
	1	3	Heading	
	0	3	Heading	LSB
Dn 10	15	4	Steering actuator Pos.	MSB
	14	4	Steering actuator Pos.	
	13	4	Steering actuator Pos.	Right Actuator for Dual Steer
	12	4	Steering actuator Pos.	Right Actuator for Dual Steer
	11	4	Steering actuator Pos.	Right Actuator for Dual Steer
	10	4	Steering actuator Pos.	Right Actuator for Dual Steer
	9	4	Steering actuator Pos.	Right Actuator for Dual Steer
	8	4	Steering actuator Pos.	Right Actuator for Dual Steer
	7	4	Steering actuator Pos.	Right Actuator for Dual Steer
	6	4	Steering actuator Pos.	Right Actuator for Dual Steer

5	4	Steering actuator Pos.	Right Actuator for Dual Steer
4	4	Steering actuator Pos.	Right Actuator for Dual Steer
3	4	Steering actuator Pos.	Right Actuator for Dual Steer
2	4	Steering actuator Pos.	Right Actuator for Dual Steer
1	4	Steering actuator Pos.	
0	4	Steering actuator Pos.	LSB

Ground Target Proportional Telemetry (Continued)

Word #	Bit#	PRT#	PRT Name	Comments
Dn 11	15	5	Filtered Heading	MSB
	14	5	Filtered Heading	
	13	5	Filtered Heading	
	12	5	Filtered Heading	
	11	5	Filtered Heading	
	10	5	Filtered Heading	
	9	5	Filtered Heading	
	8	5	Filtered Heading	
	7	5	Filtered Heading	
	6	5	Filtered Heading	
	5	5	Filtered Heading	
	4	5	Filtered Heading	
	3	5	Filtered Heading	
	2	5	Filtered Heading	
	1	5	Filtered Heading	
	0	5	Filtered Heading	LSB
Dn 12	15	6	Heading Rate	MSB
	14	6	Heading Rate	
	13	6	Heading Rate	
	12	6	Heading Rate	
	11	6	Heading Rate	
	10	6	Heading Rate	
	9	6	Heading Rate	
	8	6	Heading Rate	
	7	6	Heading Rate	
	6	6	Heading Rate	
	5	6	Heading Rate	
	4	6	Heading Rate	
	3	6	Heading Rate	
	2	6	Heading Rate	
	1	6	Heading Rate	
	0	6	Heading Rate	LSB

Ground Target Proportional Telemetry (Continued)

Word #	Bit#	PRT#	PRT Name	Comments
Dn 13	15	7	Cycles/Second	MSB
	14	7	Cycles/Second	
	13	7	Cycles/Second	
	12	7	Cycles/Second	Value is the number of passes
	11	7	Cycles/Second	through the VBS main control
	10	7	Cycles/Second	loop in the previous one
	9	7	Cycles/Second	second interval. Value may
	8	7	Cycles/Second	be used for accurate scaling
	7	7	Cycles/Second	of the heading rate (PRT 6)
	6	7	Cycles/Second	value from the heading filter.
	5	7	Cycles/Second	
	4	7	Cycles/Second	
	3	7	Cycles/Second	
	2	7	Cycles/Second	
	1	7	Cycles/Second	
	0	7	Cycles/Second	LSB
Dn 14	15	8	Throttle Position	MSB
	14	8	Throttle Position	
	13	8	Throttle Position	Usually Not Installed
	12	8	Throttle Position	Usually Not Installed
	11	8	Throttle Position	Usually Not Installed
	10	8	Throttle Position	Usually Not Installed
	9	8	Throttle Position	Usually Not Installed
	8	8	Throttle Position	Usually Not Installed
	7	8	Throttle Position	Usually Not Installed
	6	8	Throttle Position	Usually Not Installed
	5	8	Throttle Position	Usually Not Installed
	4	8	Throttle Position	Usually Not Installed
	3	8	Throttle Position	Usually Not Installed
	2	8	Throttle Position	Usually Not Installed
	1	8	Throttle Position	
	0	8	Throttle Position	LSB

Ground Target Proportional Telemetry (Conclusion)

Word #	Bit#	PRT#	PRT Name	Comments
Dn 15	15	9	Left Actuator Position	MSB
	14	9	Left Actuator Position	
	13	9	Left Actuator Position	Dual Steer Only
	12	9	Left Actuator Position	Dual Steer Only
	11	9	Left Actuator Position	Dual Steer Only
	10	9	Left Actuator Position	Dual Steer Only
	9	9	Left Actuator Position	Dual Steer Only
	8	9	Left Actuator Position	Dual Steer Only
	7	9	Left Actuator Position	Dual Steer Only
	6	9	Left Actuator Position	Dual Steer Only
	5	9	Left Actuator Position	Dual Steer Only
	4	9	Left Actuator Position	Dual Steer Only
	3	9	Left Actuator Position	Dual Steer Only
	2	9	Left Actuator Position	Dual Steer Only
	1	9	Left Actuator Position	
	0	9	Left Actuator Position	LSB
Dn 16	15	10	Multiplexed Telemetry	MSB
	14	10	Multiplexed Telemetry	

13	10	Multiplexed Telemetry	IF DIT31 (Shift In Progress)
12	10	Multiplexed Telemetry	value is VBS commanded RPM
11	10	Multiplexed Telemetry	ELSEIF DIT36, value is right.
10	10	Multiplexed Telemetry	steer point
9	10	Multiplexed Telemetry	ELSE value is left steer point.
8	10	Multiplexed Telemetry	
7	10	Multiplexed Telemetry	When steering values are
6	10	Multiplexed Telemetry	downlinked, the value
5	10	Multiplexed Telemetry	is the result of the automatic
4	10	Multiplexed Telemetry	steering calibration from the
3	10	Multiplexed Telemetry	VBS, IF DIT37 is true.
2	10	Multiplexed Telemetry	ELSE is default steer value.
1	10	Multiplexed Telemetry	
0	10	Multiplexed Telemetry	LSB

Appendix D

<<- VFd Unit Test Mode (Ground Target or F-100)->>
(from drone)

Downlink Telemetry F-100 or Ground Target

Word#	Bit#	Data	Comments
Dn 1	15-0	9804	This designates a drone frame of 4 words in length.
Dn 2	15-0	AASS	This is the address and status of the drone. It is the same format as for the Command & Control message.
Dn 3	15-0	DDDD	This is the firmware date stamp in Julian notation. Further explanation is given below.
Dn 4	15-0	SSSS	This word will be the status of the last BIT from the VBS. Presently only bit 0 is used, with a 1 bit signifying pass.

The firmware date stamp is in Julian notation; i.e. the first digit signifies the year, and the next three digits signify the day of the year. Example:

HEX	DEC	English
10AA	4266	September 23, 1994